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TNO report

V9009

Development of a mechanistic model for the Advanced REACH Tool (ART)

- Version 1.0 –

(Updates previous beta version September 2009)

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CHAPTER 1

INTRODUCTION

1 Introduction

1.1 Exposure assessment under REACH

Under REACH (Registration, Evaluation and Authorization of CHemicals), the new chemicals policy in Europe, exposure scenarios form an essential basis for chemical risk assessment reports to show that chemicals can be used safely. An exposure scenario comprises a set of conditions that describe how the substance or preparation is manufactured or used during its life cycle and how the manufacturer or importer controls, or recommends downstream users to control, exposures of humans and the environment. The derivation of these recommendations requires specific measured exposure data or generic exposure assessment tools that can predict exposure distributions in a large variety of use scenarios. The new chemicals policy in Europe and more specifically the exposure scenario concept is described in more detail in Guidance documents (ECHA, 2008).

In the REACH Guidance a tiered approach is proposed in which the first tier should provide a conservative (i.e. protective) system that can discriminate between substances in scenarios of some concern and those which are not (ECHA, 2008). In this first step, sophisticated modelling is not needed as long as the assessment overestimates the exposure. The precautionary principle dictates a conservative or “worst case” approach to safeguard worker health in Europe. How high this conservatism ought to be is a matter of debate. The decision is essentially a trade off between optimising the ability to detect true risk scenarios on one side and usability of a system on the other. Ultimately, this comes down to the question about what level of uncertainty is acceptable for the society. This question is not explicitly considered in the Guidance documentation so far.

Various screening tools such as the ECETOC Targeted Risk Assessment (TRA) (ECETOC, 2004), Stoffenmanager (Marquart *et al.*, 2008; Tielemans *et al.*, 2008b), and Easy-to-use workplace control scheme for hazardous substances (EMGK (http://www.reach-helpdesk.de/en/Exposure/Exposure.html) may be good candidates. The RISKOFDERM model is proposed in the Guidance documents as an approach for dermal exposure (Marquart et al., 2006; Warren et al., 2006). Where it is not possible to rule out the possibility of any risk to health based on the first tier exposure estimates, chemicals should then be considered at a higher tier that will provide an additional level of confidence and sensitivity. More sophisticated exposure models or already available exposure measurements may be used in a tier 2 assessment to more precisely determine exposure levels. Yet, a case-by-case assessment based on additional exposure measurements for each chemical of concern is generally considered impracticable and would be an expensive and slow process. Hence, a generic higher tier exposure assessment tool generating scientifically justified and realistic exposure estimates would significantly increase cost-effectiveness of REACH.

The lack for such a tool and the need for a robust way forward in this respect was clearly articulated in various workshops and documents (Creely et al., 2005; Northage, 2005), suggesting an approach that makes full use of mechanistically modelled estimates of exposure and any relevant measurements of exposure. A proposal for such a research program was published subsequently (Tielemans et al., 2007) and is currently referred to as the Advanced REACH Tool or ART project. This is a large collaborative project with TNO, HSL, IOM, NRCWE, BAuA, and IRAS. The mechanistic model derived in the context of this project will be described in this report. This report is an update of a previously (September 2009) published report on the beta version of the ART mechanistic model. Major changes in the mechanistic model include the additions made for metal specific scenarios (Eurometaux), activities with volatile substances (SHELL), and exposure scenarios within the pharmaceutical industry (GlaxoSmithKline) to adapt / improve the ART model for these various exposure scenarios.

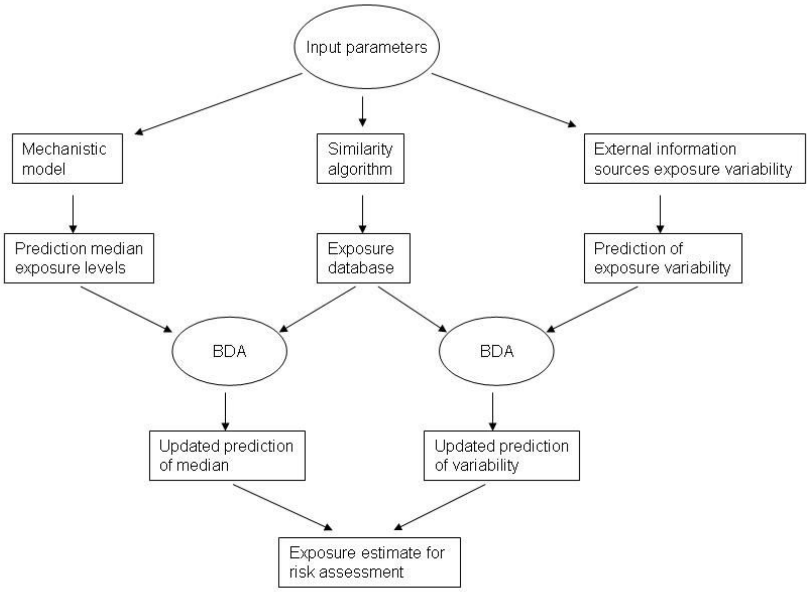
1.2 Structure of ART

The new ART framework incorporates both a mechanistic model and an empirical part with information from an exposure database. Both parts are to be combined in order to produce more precise estimates for specific exposure scenarios. The exposure database contains the relevant contextual information with respect to modifying factors of the mechanistic model. A similarity algorithm provides a proper weighing of the available data based on this contextual information. The tool also facilitates the inclusion of specific exposure data that become available to support for instance chemical safety reports.

The proposed approach follows a Bayesian statistical framework to integrate sources of information. Bayesian ideas are increasingly used to mathematically refine expert opinions or model outputs with actual exposure measurements (Ramachandran and Vincent, 1999; Ramachandran et al., 2003; Cherrie et al., 2004; Hewett et al., 2006). Most exposure assessors in regulatory risk assessment already act in some sense as Bayesian practitioners, since they often have to supplement limited data of poor quality with subjective judgements. In a more formal Bayesian framework, the integration can be done in an objective and transparent manner.

The structure of ART is schematically depicted in Figure 1.2.1. The model provides a separate estimate of the central tendency and variability of the exposure distribution in a particular exposure scenario. The underlying mechanistic model produces an estimate of the median exposure value in an exposure scenario. The prediction of the exposure variability will in first instance be based on available sources of between- and within-worker components of variability in homogeneous exposure groups as described in the literature (Kromhout et al. 1993; Symanski et al., 2006). Both the estimate for the median and exposure variability will be updated using relevant exposure data from the database. The similarity algorithm for selecting and ranking analogous exposure data is based on the same algorithm as used in the mechanistic model. The combination of the updated predictions of median and variability provides estimates of the whole distribution of exposure variability and uncertainty, allowing producing a variety of realistic and Reasonable Worst Case (RWC) exposure estimates dependent upon the requirements of the particular risk assessment. Version 1.0 of ART contains a facility to update mechanistic model estimates with fully analogous exposure data. A built-in exposure database will be included in the next version of ART.

Figure 1.2.1 Schematic structure of ART



1.3 Scope of report

The ART project comprises of several main components; i.e. development of a mechanistic model, Bayesian model, exposure database, software development, and testing and validation. This report will focus on the development of the mechanistic model. The conceptual model development as well as characterization of the principal MF is described in this report, whereas its calibration with exposure measurements will be described separately.

The mechanistic model development started with a conceptual framework (Tielemans *et al.*, 2008a). This framework defines the principal modifying factors (MF) and provides a methodology for clustering occupational activities into Activity Classes. This chapter also classifies the various types of products that can be handled (e.g. powders, volatile liquids, etc.) and exposure forms (e.g., dusts, vapours, aerosols, etc.) that can result from handling these products. A detailed description of the principal MF and underlying determinants is given in chapter 3. This also resulted in the assignment of relative scores to the various categories of the principal MF. Chapter 4 provides an overall overview of the workflow of the mechanistic model. Finally, in chapter 5 conclusions are drawn and recommendations given for future use and development. Various parts of this report are, or will be published as separate papers in the peer reviewed literature.

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CHAPTER 2

CONCEPTUAL FRAMEWORK

2 Conceptual framework

2.1 Introduction

The conceptual model is a first step in developing a more detailed quantitative model. The framework presented in this chapter helps to understand the exposure processes and transport of contaminants from the source to the receptor. On a high level of abstraction four mechanisms for transport are considered: i.e., release of contaminant from the source to adjacent air (source strength), further transport from source to receptor, loss of contaminant due to sinks, and uptake by the receptor. These four mechanisms can be described further by the definition of so called principal Modifying Factors (MF), as will be discussed in this chapter.

However, the two principal MFs related to the source (i.e. activity emission potential and substance emission potential) cannot be generically described for all occupational situations. Across the whole spectrum of activities different aspects may be relevant to characterize the principal MF ‘activity emission potential’. Similar, the principal MF ‘substance emission potential’ may have to be characterized differently for different types of products that are handled. Therefore a taxonomy of activities and products is proposed to provide a method of structuring activities and products into generic categories. The basic idea is that it is possible to transparently characterize these source-related MFs within the generic categories.

2.1.1 Scope of chapter

The conceptual model describing a stepwise transport of a contaminant from source to receptor will be discussed in paragraph 2.2. The source component of the conceptual model is elaborated on in the subsequent paragraphs. A definition of categories for further modelling of the principal MF ‘substance emission potential’ is described in paragraph 2.3. A taxonomy for occupational activities is provided in paragraph 2.4. This scheme facilitates the clustering of activities in so called Activity Classes.

2.2 Conceptual Model for Assessment of Inhalation Exposure - Defining Modifying Factors –

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2.2.1 Abstract

The present paper proposes a source–receptor model to schematically describe inhalation exposure to help understand the complex processes leading to inhalation of hazardous substances. The model considers a stepwise transfer of a contaminant from the source to the receptor. The conceptual model is constructed using three components, i.e. (i) the source, (ii) various transmission compartments and (iii) the receptor, and describes the contaminant's emission and its pattern of transport. Based on this conceptual model, a list of nine mutually independent principal modifying factors (MFs) is proposed: activity emission potential, substance emission potential, localized control, separation, segregation, dilution, worker behavior, surface contamination and respiratory protection. These MFs describe the exposure process at a high level of abstraction so that the model can be generically applicable. A list of exposure determinants underlying each of these principal MFs is proposed to describe the exposure process at a more detailed level. The presented conceptual model is developed in conjunction with an activity taxonomy as described in a separate paper. The proposed conceptual model and MFs should be seen as 'building blocks' for development of higher tier exposure models.

2.2.2 Introduction

Exposure models are an indispensable element of exposure assessment as we will never be able to measure each exposure scenario (Jayjock et al., 2007). However, establishing quantitative relationships between personal exposure levels and their determinants remains challenging, which is well reflected in the diversity of published exposure models. One approach to help understand the inhalation exposure process has been to use a source–receptor model (Smith et al., 1991) and to describe exposure schematically by deterministic exposure modifiers (Schneider et al., 1991; Woskie et al., 1995; Creely et al., 2005). Schneider et al. (1991) proposed the use of exposure factors based on 'first principles' that were mutually independent. A mechanistic model based on this approach has been developed by Cherrie and colleagues (Cherrie et al., 1996; Cherrie and Schneider, 1999). Since the latter model is flexible and involves many steps that need expert judgment, the provision of high-quality guidance is important (Semple et al., 2001). This model has been validated to some extent against workplace measurements (Cherrie and Schneider, 1999; Semple et al., 2001; Cherrie et al., 2004). Recently, the model has been used to develop a screening model called Stoffenmanager (Marquart et al., 2008), which has been calibrated using a comprehensive set of measurements (Tielemans et al., 2008). A similar conceptual approach was used for dermal exposure (Schneider et al., 1999) and resulted in a transparent algorithm for dermal exposure assessment (Van Wendel de Joode et al., 2003, 2005a,b). In the present paper, we elaborate on the prior methodological work to describe inhalation exposure schematically and to impose structure on the description of the complex processes leading to inhalation exposure. It is envisaged that the source–receptor model and its visual depiction will improve the understanding of processes leading to inhalation exposure. The conceptual framework can be seen as the 'building blocks' for the development of a new higher tier exposure model (Advanced REACH Tool) (Tielemans et al., 2007).

2.2.3 A source-receptor model

The conceptual model is based on a stepwise transport of a contaminant from the source to the receptor (Smith et al., 1991; Creely et al., 2005). It is constructed using three types of components, i.e. sources, compartments through which the contaminants may pass from the source to the receptor, and the receptor. The model includes four mechanisms for transport of a contaminant: (i) separation of gas or vapor molecules or solid particles from the parent material (source strength) (ii) transport of the contaminant to and between compartments, (iii) loss of contaminants from compartments due to sinks (e.g. local ventilation, cleaning) and (iv) uptake by the receptor (Fig. 1). This paper first describes the components and transport mechanisms and then proposes an approach to their quantification by using modifying factors (MFs).

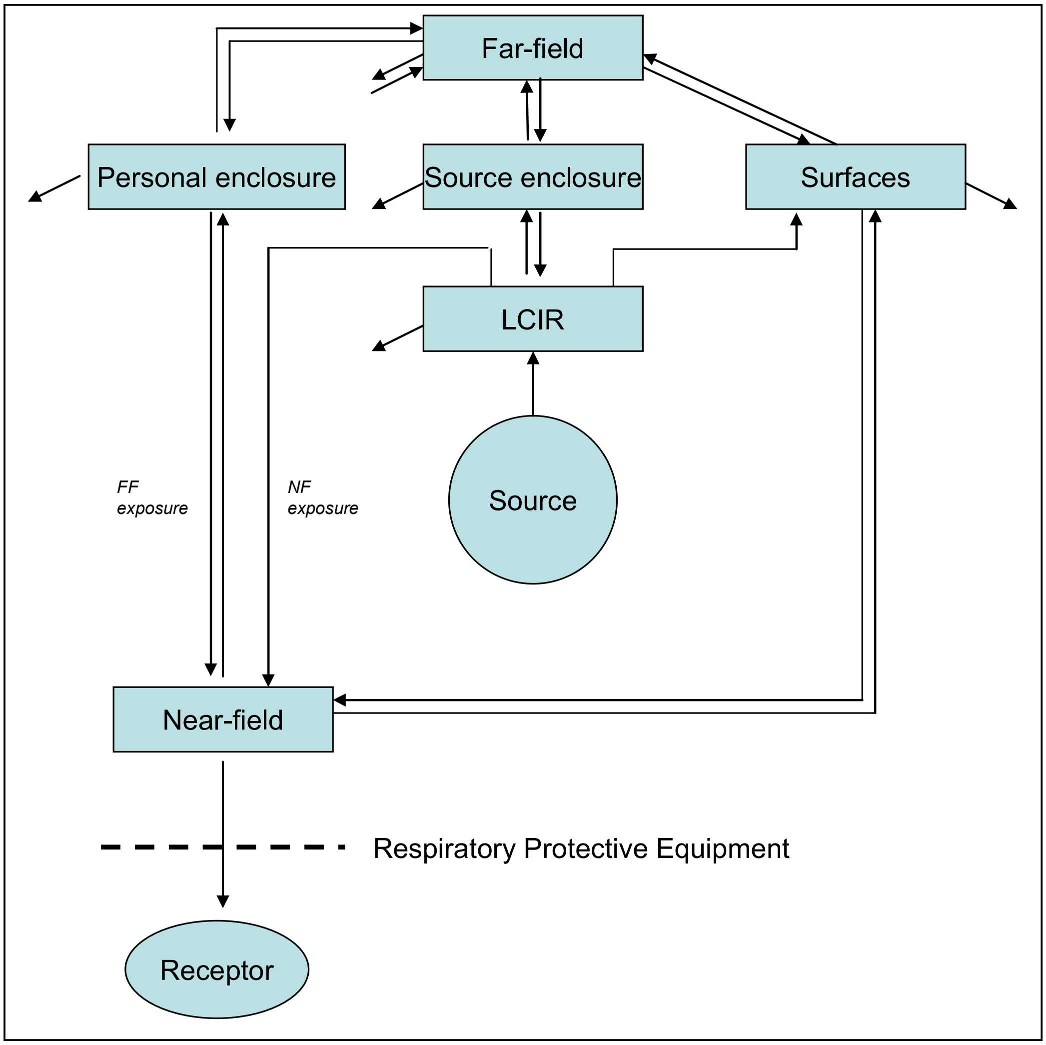

Figure 2.2.1 Conceptual model for inhalation exposure including sources, compartments and receptor and transport between these components

2.2.3.2 Model components

Source

The source component represents an activity during which a hazardous substance is emitted into the air. The source can be either stationary or mobile and the strength of the source is dependent on characteristics of the activity and features of the product itself (Plinke et al., 1991). The constrained transport of energy to the parent product related to an activity causes a substance to be released from the parent product and to become airborne. Once molecules or particles have been separated from the parent material, induced air movements will transport the liberated material away from the source. In theory, a source may also be diffuse and difficult to localize, e.g. emission due to leaking machinery. Spills or other contaminants on surfaces are included in the surface compartment.

Compartments. Local control influence region

A virtual boundary around a source is proposed. This boundary delimits the ‘local control influence region’ (LCIR) and represents the zone of influence for a given local control system. The LCIR boundary may be determined by a physical barrier to contain the substance (e.g. screens or airborne capture sprays) and the range of influence of the local exhaust ventilation (that would be determined by capture velocity, type of hood, etc.). The local exhaust ventilation is also a sink that removes contaminant from the LCIR. More than one local control and thus LCIR may be related to a particular source.

Near-field and far field

The near-field (NF) compartment is conceptualized as a volume of air within 1 m in any direction of the worker’s head. The far field (FF) comprises the remainder of the room. Hence, the concept of NF–FF can be considered as a box-inside-of-a-box, where the worker moves around in the FF zone with an enveloping NF zone. In the proposed conceptual model, a source is referred to as an NF source or an FF source depending on its location relative to the worker. The boundaries of the NF are somewhat arbitrary chosen and follow previous work by Cherrie and Schneider (1999). Others have proposed a two-zone approach, where the NF zone is centered around the source instead of the worker (Nicas, 1996; Spencer and Plisko, 2007). However, we prefer to define the NF around the worker as this places the focus on the worker and hence personal exposure. The concentration decreases with increasing distance from the source due to mixing with background air. In many cases, the mixing is caused by a nondirectional, random airflow resulting in uniform dispersion. The airflow in workrooms arises mainly from turbulent motion of the air and so-called eddies due to obstacles in the path of moving air, localized convection currents induced by temperature differences and movement of machines and workers (Roach, 1981). The present approach lumps concentration gradients into the two compartments NF and FF. This approach assumes perfect mixing in the two compartments with transport between the two compartments due to local airflows and turbulence. The airflows are dependent on features like room shape and size, general ventilation, movement of other workers or equipment (e.g. fork-lift trucks), convection from heat sources in the room and the physical work rate of the worker. The processes determining these airflows are poorly understood (Feighley et al., 2002). However, theoretical work of Cherrie (1999) showed that some general assumptions can be made about the effects of room size and general ventilation characteristics on the relationship between concentrations in the NF and FF zones. The assumption of perfect mixing may lead to substantial error in exposure assessment where workers are positioned very close to the source. Moreover, the perfect mixing assumption does not consider local disturbances in the flow field very close to the worker. Examples of factors that may have impact on contaminant levels in the breathing zone are convection as a result of body temperature, formation of wakes or arm movements (Flynn and George, 1991; Flynn and Ljungqvist, 1995; Welling et al., 2000). These phenomena may be simulated using specific computational fluid dynamics (Bennett et al., 2000), but cannot be explicitly dealt with in generic models. In the present approach, this problem is dealt with by introducing a MF, to be described later. The conceptual model is specifically focusing on indoor worker environments. Modifications will be needed for describing the dispersion pattern in outdoor situations.

Source enclosure and personal enclosure

Additional compartments defined by enclosures can be added if relevant. A source, for example, may be placed in a compartment that isolates the source from the work environment. This compartment is referred to as the source enclosure. Likewise, a worker may be inside an air-conditioned cabin; this compartment is referred to as a personal enclosure.

Surfaces

Surfaces (e.g. workbench, wall, but also personal clothing) that have been contaminated by the chemical of interest through general deposition in the work environment or adsorption constitute the surface compartment or several distinct compartments if needed. The deposition may result in permanent loss of contaminant, e.g. due to cleaning activities. Alternatively, surface contaminants may be transported to the NF or FF compartment through resuspension or evaporation, e.g. due to moving equipment, worker movement and draughts. The transport rate of contaminants from the surface compartment is difficult to predict and depends on, among others, factors such as cleaning procedures and level of ‘good house keeping’ (Buringh et al., 1992; Lumens et al., 1993). It is important to note that treated or contaminated surfaces that constitute a clearly defined source of emission (e.g. handling of treated objects, treated surfaces during brushing, drying rack) are addressed as a source component.

Receptor

This component represents the respiratory tract of the worker. Respiratory protective equipment (RPE) forms a barrier for air contaminants that reduces uptake by the receptor.

2.2.3.3 Transport mechanisms

Figure 2.2.1 also shows the transport of contaminant between model compartments representing the exposure pathways from the source to the worker (indicated by the arrows between compartments). Some arrows leave the compartments without leading to other compartments, signifying losses from the system. For example, the arrow leaving the LCIR compartment indicates the loss of contaminant mass removed by a local control measure. The rate at which a contaminant is emitted from the source is the gross source output rate, expressed asmass per unit time. A fraction of the emitted contaminant escapes the LCIR compartment and the corresponding transport rate is the net source output rate. Turbulence and large eddies subsequently transport the airborne contaminant directly to the NF or to the FF depending on the location of the source. Where a source or a personal enclosure exists, the source is by definition in the FF. In case of a source enclosure, part of the contaminant is removed and the remaining fraction is transported to the FF. In a similar fashion, the personal enclosure (e.g. when the worker carries out an activity within a cabin) reduces contaminant transport to the NF. Contaminants may also be transported to surrounding surfaces; a fraction may leave the system due to cleaning or other loss processes and by evaporation or resuspension a fraction may again be transported to the NF or FF. The model depicts one source component, although in reality multiple sources are often present in a workplace. All these sources will release contaminants and transport of these contaminants will follow the processes as indicated in Fig. 2.1.

2.2.4 Quantitative exposure estimation algorithm

2.2.4.1 Modifying factors

Nine principal MFs are proposed that are associated with the model components: two for the source component and one for each of the other model components (Table 2.2.1).

Table 2.2.1 Components of the conceptual model and related principal Modifying Factors

Model component	**Principal MF**	**Description**
Source	Activity emission potential (*H*)*	Describes the potential of the activity to generate exposure and is determined by the following characteristics: type and amount of energy transfer, scale (*e.g.* amount product used), and product to air interface (e.g. level of containment).
	Substance emission potential (*E*)	Determines the intrinsic emission potential of a substance, *i.e.*: dustiness for particulate agents and volatility for liquids.
Local control influence region (LCIR)	Localized control (*LC*)	Control measures in close proximity of the source intended to remove emissions, *e.g.* local exhaust ventilation (LEV), airborne capture sprays.
Source enclosure	Segregation (*Seg*)	Isolation of sources from the work environment without containment of the source itself, *e.g.* separate drying room.
NF and FF zone	Dilution (*D*)	Natural and mechanical ventilation characteristics, determining the dilution of air contaminants through the room: *i.e.*, between NF - FF zone, and FF - outside.
NF zone	Personal behavior (*P*)	Orientation and distance of the worker to the source in the near-field, determining the potential exposure, *e.g.* worker positioned at very close distance during precision work, overhead work.
Personal enclosure	Separation (*Sep*)	Providing a worker with a personal enclosure within a work environment, *e.g.* air conditioned cabin.
Surfaces	Surface contamination (*Su*)	Emission related to release of deposited contaminants on surrounding surfaces (including worker clothing) due to natural means or general workplace activities (e.g. moving equipment / vehicles).
Receptor	Respiratory protective equipment (*RPE*)	Efficiency of RPE preventing the inhalation of airborne substances (not addressed in this paper).

* This principal MF is described in detail in an accompanying paper (Marquart *et al* 2008b)

The MFs are defined at a high level of abstraction in order to be applicable across a broad range of scenarios. The MFs are defined so that they are virtually mutually independent from a physico-chemical point of view. In order to be useful for exposure modeling, these MFs have to be uniquely identifiable, observable, quantifiable and be applicable across a wide range of different exposure scenarios. Each MF has a number of underlying determinants that are defined at a low level of abstraction and thus much more specific; examples of these underlying factors are discussed later. The emission rate at the source is a function of the type of activity and characteristics of the substances used. The MF ‘activity emission potential’ describes the potential of the activity to transport contaminants into the LCIR compartment and is determined by characteristics such as type (e.g. motive forces, heat) and amount of energy transfer, scale (e.g. amount product used) and product-to-air interface (interaction between product and adjacent air). The ‘substance emission potential’ describes the potential of the product to become airborne. For particulate agents, the potential to become airborne is dependent on dustiness. For liquids and liquid mixtures, the potential to become airborne is dependent on volatility. The LCIR is related to the principal MF ‘localized control’, representing the efficiency of control measures in close proximity of the source. The impact of a source enclosure is accounted for by ‘segregation’, describing the effectiveness of isolation of sources from the work environment. A ‘dilution’ factor describes the influence of mechanical and natural ventilation and room size on the concentration in the NF or FF compartments. The principal MF ‘worker behavior’ is defined to take account of the influence due to worker movement, worker posture, possible worker posture very close to the source and other factors causing deviations from a completely mixed NF. The principal MF 'separation' describes how effective the concentration in the personal enclosure compartments is reduced relative to the FF in which it is embedded. Note that a personal barrier, if present, encapsulates the person and could thus be taken as the NF zone. Transport into NF or FF due to release of deposited contaminants on surfaces is described by the principal MF 'surface contamination'. The MF 'respiratory protective equipment' is not addressed in this paper.

2.2.4.2 Structure of algorithm

Esmen (1979) used MFs in a multiplicative manner for retrospective exposure assessment. However, as previously proposed by Cherrie and Schneider (1999), we treat the various exposure sources in the NF and FF zones as additive terms, while MFs describing release and dispersion of a particular source are incorporated in a multiplicative manner. The algorithm from Cherrie and Schneider (1999) is extended using the list of nine principal MFs in the equations below. The total personal exposure level (C_t) is the sum of exposure levels due to NF (C_{nf}) and FF (C_{ff}) contributions, adjusted for possible use of RPE:

$$C_t = (C_{nf} + C_{ff}) \cdot RPE \qquad \text{Equation 2.1}$$

Personal exposure due to sources in the NF (C_{nf}) is a multiplicative function of substance emission potential (E), activity emission potential (H), localized control (LC), personal behavior (P) and dilution (D). In addition, exposure may arise due to transport of substance from surfaces in the NF [surface contamination (Su)]:

$$C_{nf} = (E_{nf} \cdot H_{nf} \cdot LC_{nf} \cdot P_{nf} + Su_{nf}) \cdot D_{nf} \qquad \text{Equation 2.2}$$

Personal exposure due to sources in the FF (C_{ff}) is a multiplicative function of substance emission potential (E), activity emission potential (H), localized control (LC), segregation (Seg), dilution (D) and separation (Sep). In addition, exposure may arise due to transport of substance from surfaces in the FF [surface contamination (Su)]:

$$C_{ff} = (E_{ff} \cdot H_{ff} \cdot LC_{ff} \cdot Seg_{ff} + Su_{ff}) \cdot D_{ff} \cdot Sep_{ff} \qquad \text{Equation 2.3}$$

Note that there are differences between equations describing exposure related to NF and FF sources. Segregation and separation are not relevant for NF sources, whereas the personal behavior is not relevant for FF sources. The factor dilution will be different for FF sources as compared to NF sources. Cherrie (1999) has suggested numerical values for this factor for NF and FF sources on a relative scale. The equations apply for a situation where operational conditions remain stable. In complex work environments, multiple sources of various source strengths may be present in both the NF and FF. In theory, the contribution of each source should be calculated separately and then added for the NF and FF. In practice, however, it may not be feasible to take into account all sources. A pragmatic solution may be to take into account only the main sources in the NF and FF. In case that a person is conducting different consecutive tasks during a time period, each task should be assessed separately and a time-weighted average should be calculated.

2.2.4.3 Quantification

In order to use the equation to predict a concentration unit (e.g. mg/m^3), different approaches can be followed. From a mechanistic point of view and following from the conceptual framework, the substance emission potential can be assigned the unit of an emission rate (mass per time unit), whereas the dilution has the unit of a reciprocal of a ventilation rate (time unit per volume). The other principal MFs are dimensionless. Alternatively, Cherrie and Schneider (1999) followed a more pragmatic approach that proved to be feasible in various work situations. They assigned unit of concentration to the substance emission potential, whereas the other terms were defined as dimensionless quantities. Hence, this approach represents the concentration generated during a standardized task and operational conditions. This approach of assigning a ‘target value’ has shown to be successful in the quantitative assessment of different exposures across 40 tasks (Semple et al., 2001). Finally, all MFs may be defined as dimensionless quantities operating on a given baseline estimate. The latter approach has been used to estimate historical exposure by multiplying contemporary exposure measurement results by dimensionless exposure modifiers (Armstrong et al., 1996; Lewis et al., 1997). The dimensionless algorithm may also be fitted to available exposure measurements using regression techniques to arrive at an equation predicting a concentration unit. Recently, a screening level model called Stoffenmanager has been calibrated in this manner (Tielemans et al., 2008). Mixed-effects models were used to enable the mechanistic model to predict actual exposure rather than just relative exposures.

2.2.5 Underlying determinants of exposure

Abroad range of exposure determinants has already been documented in exposure assessment studies (Burstyn and Teschke, 1999). Important determinants that are observable at the workplace are briefly discussed here; Table 2.2.2 describes underlying determinants related to the source component, whereas the underlying determinants of the remainder of the principal MFs relevant for transport between and loss from compartments are described in Table 2.2.3. Both tables provide some important examples of underlying determinants but should not be considered to be comprehensive. We are currently assigning values to the principal MF and in the context of this subsequent work we will describe the underlying determinants and related literature in more detail in the future.

2.2.5.1 Determinants related to the source

The principal MF activity emission potential can be characterized in relation to three categories of determinants. First, emission is dependent on the level and type of transfer of energy. The type of energy transfer can be very diverse and to adequately describe this MF, the type of energy transfer is divided into five classes:

1. Motive forces—emissions primarily related to movement of product or movement of objects contaminated with a product. It excludes motion where friction is caused between bound materials.
2. Gravitational and impaction forces—emissions primarily related to forces during falling and caused by the final impact on surfaces.
3. Friction—emissions primarily caused during an activity where friction between bound materials and collisions induced by friction causes comminution. The target product may include (lubricating) liquids added to these activities.
4. Pressure drop and other dispersion forces—emissions primarily caused by pressurized sources or other forces/techniques causing intentional or unintentional dispersion into the air.
5. Heat—the emission (generally of vapors) is largely from the temperature of a product that, together with the temperature of the surrounding of the product, leads to emission of vapors. Heat energy may be actively applied, e.g. when a liquid is heated, it may be the result of a chemical reaction process, but it may also be passively present, e.g. when there is evaporation from a liquid at room temperature.

Table 2.2.2 Principal modifying factors related to source strength and examples of underlying determinants

Principal Modifying Factor	**Underlying determinants**
Activity emission potential	*Type and amount of energy transfer:* • Motive forces (non-frictional). Amount is determined by e.g., level of agitation, velocity, reactivity • Gravitational and impaction forces. Amount is determined by e.g., dropping height, hardness of receiving surface • Frictional forces. Amount is determined by e.g. velocity, capacity, friction coefficient • Pressure drop and other dispersion forces. Amount is determined by e.g., pressure, level of dispersion force • Heat. Amount is determined by e.g., processing temperature (melted solids), voltage, agitation *Scale:* • Application rate (kg or l/hr), amount produced or processed per time (m^3/hr) • Level of surface loading, surface area handled *Product-to-air interface:* • Confinement technologies (*e.g.* closed system, closed but breaching system, lids on vessels, hatches) • Specialized technologies (*e.g.* bottom-loading)
Substance emission potential	*Dustiness:* • particle size (distribution) • aggregation / coalescence / cohesion / friability • moistness of product (if not related to airborne capture sprays) • solidity / intactness / corrosion / surface modification of bound materials *Volatility:* • partial vapour pressure, diffusion coefficient in air

Second, the scale of the activity is relevant in terms of emission potential. The influence of scale will depend on the type of activity and material. For instance, scale can be expressed in terms of processing rate of a product, i.e. amount of product produced or number of pieces processed per time unit (e.g. for weighing a product). Alternatively, surface contamination or surface area may be a more relevant underlying determinant of scale in other activities (e.g. for working with a vapor degreasing bath). It should be noted that level of energy transfer and scale during an activity may be influenced by personal behavior and skills of the individual worker. One may for instance envisage that less skilled workers may handle substances in a more uncontrolled manner resulting in more energy transfer.

Third, product-to-air interface describes an activity in terms of the extent to which the substance interacts with the adjacent air. Again, the product-to air interface can be described in different ways. For activities where the product is intentionally transferred through the air or displaced across surfaces, the interaction may be influenced by e.g. surface area, surface characteristics (e.g. influencing retention), application techniques and transfer characteristics (e.g. transfer efficiency). Product-to-air interface may be closely related to scale of the activity and as such cannot be considered completely independent. For different activities, various combinations of the above determinants may be applicable, implying that different combinations of underlying exposure determinants are relevant across the whole spectrum of occupational activities. Hence, identification of the underlying determinants of the activity emission potential is difficult in a generic sense. Therefore, a clustering scheme is proposed in a separate paper (H. Marquart, T. Schneider, H. Goede, M. Tischer, J. Schinkel, N. Warren,W. Fransman, M. van Tongeren, H. Kromhout, E. Tielemans, J. Cherrie, 2008, in preparation) that provides a method of structuring activities in generic groups characterized by processes that are similar regarding type of energy transfer, scale and product-to-air interface. Such a clustering scheme was used earlier for modeling dermal exposure (Van Hemmen et al., 2003). This helps to subsequently assign scores for this principal MF, separate for different generic groups.

Table 2.2.3 Principal modifying factors related to dispersion and examples of underlying determinants

Principal Modifying Factor	**Underlying determinants**
Local control	*Local exhaust ventilation (LEV):* • type of exhaust system (*e.g.* LEV type, capture velocity, distance between source & hood) • LEV enhancements (*e.g.* encapsulation, air-supply at/behind worker) • critical conditions of use (good / poor practice) • maintenance of system *Suppression techniques:* • type of airborne capture sprays • thoroughness of wetting (*e.g.* velocity & quantity water used, angle nozzles) • enhancement techniques (*e.g.* finely atomized, electrostatic charging, foams, surfactants, fog) *Chemical stabilization:* • type of chemical technique (*e.g.* volatility of suppressants) • critical conditions (*e.g.* amounts used) *Physical stabilization:* • type of physical technique (*e.g.* oil, saw dust) • critical conditions (*e.g.* amounts used)
Segregation	• type of segregation (*e.g.* curtains, screens, separate (enclosed) room, covering with foil, tarpaulins) • degree of segregation (*e.g.* partial / complete, separate room with/without extraction ventilation)
Dilution	*Indoors:* • ventilation type & design: *e.g.* natural, mechanical, special ventilation (booths, walk-in cabinets) • ventilation air flow rate and room size (nominal air exchange rate) • conditions (*e.g.* plume away/towards worker, mobile activities, obstacles between source-worker) • operation / maintenance of ventilation system *Outdoors:* • meteorological conditions (*e.g.* wind speed, wind direction, atmospheric stability)
Separation	• type of separation (*e.g.* closed room or cabin, open booth or cabin) • degree of separation (*e.g.* partial / complete, cabin with / without fresh air supply)
Personal behavior	• worker-source orientation (*e.g.* overhead work, worker posture to source, orientation of application) • worker-source distance (*e.g.* manual / automated, close-up precision work, length tool handle)
Surface contamination	• location of surface (*e.g.* clothing, nearby work surfaces) • contamination level (*e.g.* wet / dusty clothing and surfaces) • disturbances (draughts, convection, vibration, vehicles)
Respiratory protective equipment (RPE)	• type of RPE • critical condition of use (e.g., fit of device) • maintenance

The principal MF substance emission potential is determined by dustiness for particulates and volatility for liquids. Table 2.2.2 describes the distinct underlying determinants that are important with respect to dustiness and volatility. Volatility is strongly related to vapor pressure of a substance which itself is strongly related to temperature of the liquid. Substances with very high vapor pressure should be considered separately as they are already in the gas state and are by definition airborne. Likewise, at the other end of the spectrum, substances with very low vapor pressure do not evaporate and exposure occurs due to formation of aerosols as a result of handling the product. For a substance in a mixture, one should ideally use the mole fraction of the substance to predict partial vapor pressure. However, there is generally only limited information available on characteristics of a mixture. In addition, prediction of volatility for mixtures can be difficult for non-ideal mixtures (Olsen et al., 1992; Nielsen and Olsen, 1995; Fehrenbacher and Hummel, 1996). Mixtures of solids and liquids have a further complexity because the emissions are not constant with time because as the mixture dries a solid film may form over the surface. Dustiness can be defined as the propensity of a material to generate airborne dust during its handling. Dustiness is not a fixed physical or chemical property of a substance and depends on particle size, humidity and the nature of the adhesive forces (Lidén, 2006). This can be evaluated using standardized dustiness tests. Some explorative attempts have been made to study dustiness test results in relation to exposure for powdered and granular material (e.g. Brouwer et al., 2006). Dustiness characteristics have also been studied in relation to fibre exposure (e.g. Schneider, 1995). Several screening tools, such as COSHH Essentials and Stoffenmanager, incorporate dustiness in relative categories. Yet, at present, the relevance of qualitative terminology like 'coarse dust' and 'fine dust' in terms of dustiness is poorly understood and should be explored further.

2.2.5.2 Determinants related to compartments

The transport between compartments is described by the other seven principal MFs and related underlying determinants (Table 2.2.3). For localized control, a distinction can be made between underlying determinants related to local ventilation, suppression techniques, chemical stabilization and physical stabilization. The efficacy of control measures is determined by technology aspects (e.g. capture velocity), critical conditions of use and maintenance of systems (Popendorf, 2006). The effectiveness of segregation is determined by type and degree of segregation of the source. This also applies for separation. A worker may reside in a cabin or room that is completely or partially enclosed. In addition, the room may be ventilated or not. Dilution in the NF and FF zones has different underlying determinants for indoor and outdoor work. For indoor work, ventilation type, airflow rates and room size are dominant factors (Cherrie, 1999). Dilution in outdoor situations is heavily influenced by meteorological conditions and only very limited experience exists to model this for occupational exposures. The principal MF personal behavior includes the influence of working methods and is determined by both the orientation and distance between worker and source. Some activities may be very prone to behavior (e.g. manual handling of substances), whereas other activities are not prone to behaviour (e.g. remote working, working isolated from process). This principal MF can cover worker skills and habits as it has been shown by Vermeulen et al. (2000) that seniority was related to exposure, suggesting that professional skills can have impact. The relevance of surface contamination is determined by level of surface contamination and the potential for disturbances at the workplace. It is very difficult to propose objective measures for this MF, but the extent of contamination may be related to type of industry (e.g., pharmaceutical industry vs. foundries), cost of substance (less contamination when using expensive substances), and toxicity (less contamination when using obviously toxic substances). Location of the surface is very important as for instance contaminations on clothing may result in substantial exposure gradients in the NF, whereas other surfaces probably result in relatively homogeneous dispersion in the NF.

2.2.6 *Discussion*

Databases with repeated inhalation (Kromhout et al., 1993; Rappaport et al., 1993; Symanski et al., 2006) and dermal (Kromhout and Vermeulen, 2001; Kromhout et al., 2004) exposure measurements from a variety of workplaces and industries provide evidence of substantial variation between workers and even more of temporal variation. Some fundamental work describing the processes leading to this exposure variation has already been completed. Both empirical modeling of exposure data (e.g. Rappaport et al., 1999; Burstyn et al. 2000) and mechanistic modeling (e.g. Cherrie and Schneider, 1999; Keil, 2000; Nicas and Armstrong, 2003) have provided insight into sources of spatial and temporal exposure variation. The goal of this paper was to further evaluate the processes leading to inhalation exposure and to integrate these processes in a conceptual model. Considering each step in the process of inhalation exposure from the source to the worker helps to explicitly define the assumptions with respect to exposure and provides a foundation for model development. The proposed conceptual model in conjunction with the principal MF and underlying determinants should be seen as building blocks for development of a new mechanistic exposure model that is currently under development (Tielemans et al., 2007). This paper can be considered a first step in this development. The MFs as proposed in the present paper are subdivided into nine relevant and distinct classes. The optimal resolution or number of classes for each MF and the assigned values should be based on the state of the art evidence and views in the exposure assessment community. An expert elicitation procedure (Morgan and Henrion, 1990) is needed combining available empirical evidence and expert judgment to arrive at such a view. This approach will be feasible for various MF such as localized controls, segregation, separation, mixing and surface contamination. Additional methodological work on indoor and outdoor transport processes is required to adequately describe exposure in various working environments. An activity taxonomy and clustering scheme for activities needed to transparently assess exposure potential of activities has been developed by H. Marquart, T. Schneider, H. Goede, M. Tischer, J. Schinkel, N. Warren, W. Fransman, M. van Tongeren, H. Kromhout, E. Tielemans, J. Cherrie (2008, in preparation). The methodological work may also contribute to further development of other, existing exposure models such as Stoffenmanager (Tielemans et al., 2008), COSHH Essentials (Russel et al., 1998) and the ECETOC TRA (ECETOC, 2004). The opposite is also true; the absence of a formal underlying conceptual model was the basis of critique in the evaluation of EASE (Creely et al., 2005). Ideally, different screening and more advanced models for exposure assessment should all have a common underlying conceptual model, although models may differ in terms of resolution, (worst-case) assumptions, etc. In addition, the proposed list of MFs could be adopted as the basis for a standardized approach for recording core contextual information in conjunction with already existing guidelines (Rajan et al., 1997; Tielemans et al., 2002). Systematic collection of data on the MFs in new exposure studies and subsequent statistical analyses of the data ensure a growing evidence base. This may improve the ability of the model to predict exposure adequately. We are currently collating exposure data with sufficient contextual information from various institutes and industries in order to quantify the proposed mechanistic model. In the context of the Advanced REACH Tool project, part of the collated exposure measurements will be used for cross-validation of the model in a later phase.

2.2.7 *References*

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2.3 Defining categories for assessment of the principal MF ‘substance emission potential’

2.3.1 Introduction

The conceptual source-receptor model provides a list of nine mutually independent MF for prediction of inhalation exposure levels. One of the source-related MF is ‘substance emission potential’. Depending on the type of product and the way it is handled, release of a contaminant may occur in different forms (e.g. vapours, dusts). In line with this observation different features of a substance or product are relevant in terms of emission, such as vapour pressure, dustiness, etc. As is the case for ‘activity emission potential’, a systematic classification system would help to transparently classify ‘substance emission potential’ and to take into account the appropriate underlying determinants. Such a scheme for further characterization of ‘substance emission potential’ is proposed based on type of product and type of exposure that is the result of handling this product. For instance, a solid object may result in inhalable dust exposure due to abrasion or fumes due to hot work. Both situations require a different modelling of ‘substance emission potential’. First, a description of the various exposure forms is provided below.

2.3.2 Exposure forms

In order to build a generic and comprehensive exposure model all types of exposure should be considered. As the behaviour of these exposure types is fundamentally distinct, the various forms are briefly described below. These descriptions are based on definitions provided by Popendorf (2006). A main distinction can be made between gases and vapours on one side and aerosols on the other.

2.3.2.1 Gases and vapours

Gas: This is the airborne state of a chemical whose liquid is so volatile that its vapours cannot reach equilibrium with its liquid. If such a chemical were present in an open container in a closed room, all of the liquid would evaporate. This exposure form is outside the applicability domain of ART version 1.0.

Vapour: This is the airborne state of a chemical which, if a sufficiently large amount of liquid were released into a closed room at normal temperature, would not completely evaporate but would rather reach equilibrium with its liquid.

2.3.2.2 Aerosols

Aerosols are unlike vapours in at least three aspects: they lack an intrinsic property (such as vapour pressure) to become airborne, they are much larger than the air molecules in which they are suspended, and aerosols can be generated in many sizes often referred to as inhalable fraction, thoracic fraction, and respirable fraction. Various types of aerosols exist with distinct characteristics.

Dust: Solid particles that are formed by aerosolization of already existing powders or by abrasion of solid objects. A broad range of diameters is possible but those larger than approximately 100 µm in diameter will not stay airborne long.

Fume: Solid particles that are formed by condensation from high temperature vapour, such as from molten metal or smoke. Fumes form at an initially very small diameter (ca 0.01 µm); and although they will aggregate into larger particles, they still rarely get larger than approximately 0.5 µm.

Mist: Any airborne liquid particles. Water mist in the form of steam, fog, or a fine spray are common example, but mists of an organic solvent or even mercury can be formed. Mists smaller than approximately 1 µm are hard to generate, and mists larger than approximately 100 µm will not stay airborne long.

Fibre: Elongated particles whose length-to-diameter ratio is at least 3:1. A fibre's aerodynamic behaviour is determined mostly by its diameter (vs. its length).

Bio aerosols: Particles of biologic origin (plants, food, etc.). Because we do not know whether bio aerosols can be modelled similarly to other aerosols, this type of exposure is outside the scope of the mechanistic model described in this report.

2.3.3 Categories for further modelling 'substance emission potential'

The categories for further modelling of 'substance emission potential' are determined by a combination of type of product and exposure form. In Table 2.3.1 the different categories for modelling 'substance emission potential' are given.

2.3.4 Discussion

For each category proposed in Table 2.3.1 a distinct (set of) underlying determinants should be used for modelling 'substance emission potential'. The nature of the determinants across categories is very different; for liquids a well defined and intrinsic property like vapour pressure is relevant, whereas a less clearly defined and non-intrinsic feature as dustiness has to be used for powders. Hence, the modelling of the MF 'substance emission potential' will be very different for the various categories. A further quantification of 'substance emission potential' for each category will be described in chapter 3.

Given the different innate properties of the product and distinct exposure forms a separate calibration with exposure measurements will be conducted for at least each of the proposed categories in Table 2.3.1. The calibration will be described in a separate report.

Table 2.3.1 Overview of categories for modelling of 'substance emission potential'

Categories for modelling 'substance emission potential'	**Type of product**	**Type of exposure**
Handling solid objects resulting in dust exposure	Solid objects	Dust
Handling powders resulting in dust exposure	Powders, granules or pelletized material	Dust
Handling solid objects or powders resulting in exposure to fumes	Solid objects Powders, granules or pelletized material	Fumes
Handling fibrous material	Fibrous materials	Fibres

Handling liquids resulting in vapour	Volatile liquids (Vapour pressure >10 pascal)	Vapour
Handling liquid resulting in mist	Non-volatile liquids (Vapour pressure ≤ 10 Pascal)	Mist
Handling liquids resulting in fumes	Non-volatile and volatile liquids	Fumes
Handling molten or heated metal resulting in fumes	Molten or heated metal	Fumes
Handling gas	Gas	Gas

2.4 Classification of Occupational Activities for Assessment of Inhalation Exposure

- Submitted draft publication -

2.4.1 Abstract

There is a very large variety of activities in workplaces that can lead to emission of substances. Proper coding systems for such activities have so far not been developed. In this paper a system of Activity Classes and Activity Subclasses is proposed for categorizing activities involving chemical use. Activity Classes share their emission generation mechanisms and physical state of the product handled and the underlying determinants of emission. Pragmatic considerations, e.g. related to the understandability of the system by users in relevant industry sectors, also contributed to the development of the system. A number of (industrial) stakeholders actively participated in testing and fine-tuning the system. This greatly increased the connection to existing practice and terminology. With the help of these stakeholders it was found to be relatively easy to allocate a large number of activities to the Activity Classes and Activity Subclasses. The system facilitates a more structured classification of activities in exposure databases, a structured analysis of analogy of situations, and transparent quantification of the activity emission potential in (new) exposure assessment models.

2.4.2 Introduction

Exposure at the workplace is complex and many factors influence the exposure level at a given workplace in a given situation (Kromhout *et al.*, 1993). Tielemans *et al.* (2008a) recently elaborated a source-receptor model for inhalation exposure by Cherrie *et al.* (1999), using process, physicochemical properties, and mass balance to predict exposure into a conceptual model to describe mechanisms that lead to exposure. This model describes four main stages in the exposure pathway: separation of gas or vapour molecules or solid particles from the parent material (i.e. the source), followed by dispersion of the contaminant through the work area, loss of contaminant into various sinks, and then uptake by the receptor (i.e. the individual worker). Based on this conceptual model, a list of nine mutually independent principal modifying factors (MF) was proposed for prediction of inhalation exposure levels.

One of the principal MF is “Activity emission potential” that describes the potential of an activity to generate emissions into the work environment. Different features of an activity are relevant in terms of emission, such as i) the type and amount of energy transfer during an activity, ii) the scale of use, and iii) the extent of contact between product and adjacent air (the product-to-air interface). This complexity is illustrated by the fact that activities are often described in vague terms in exposure models, for example “non-dispersive use” and “low dust techniques” in the EASE model (Tickner *et al.*, 2005).

A systematic classification system would help avoid ambiguity in characterizing or quantifying activity emission potential. An activity classification was developed earlier for clustering dermal exposure situations and modeling of dermal exposure (Van Hemmen et al., 2003, Marquart et al., 2006, Warren et al., 2006), but is currently lacking for inhalation exposure. Within REACH the concept of ‘process categories’ or PROCs has been developed (ECHA, 2010). The PROCs form one of the sets of ‘use descriptors’ that enable more or less structured description of uses in REACH dossiers. They have been partly based on the handling categories used in Stoffenmanager (Marquart, et al., 2008). They also form the starting point for exposure estimates using the ECETOC TRA (ECETOC, 2004, 2009). However, these PROCs are not fully based on the emission process. They combine activity based categories, such as ‘rolling and brushing’ with more generic descriptions, such as ‘Use in closed, continuous process with occasional controlled exposure’.

In the present paper a new clustering scheme of "Activity Classes" is proposed for inhalation exposure. This scheme provides a method for structuring activities into generic groups characterized by processes with similar emission generation mechanisms and will facilitate the efficient storage of exposure data and facilitate the identification of analogous data for modeling purposes. In addition, the Activity Class concept should assist in the quantification of the activity emission potential as part of the Advanced REACH Tool or ART (www.advancedreachtool.com).

2.4.3 Activity Class concept

The activity emission potential depends on various combinations and types of energy transfer, scale, and product to air interface, as discussed by Tielemans et al. (2008a). An "activity" is here defined as a specific delimited process step with handling characteristics that differentiate it from other process steps. A simplified description of the paint production process, for example, is as follows: liquids are pumped into a mixer (activity 1), solids are added (activity 2), the mixture is mixed (activity 3) and finally it is filled into cans (activity 4). An overview of general definitions used in this paper is given in table 2.4.1. In practice, it may not always be possible to strictly distinguish different activities and a pragmatic approach will be used.

Table 2.4.1 Glossary of terminology used in this manuscript.

Activity emission potential	Describes the potential of the activity to generate exposure and is determined by the following characteristics: type and amount of energy transfer, product to air interface, and scale
Energy transfer	A substance is released from the parent material or from a contaminated surface because of energy transfer. Various types of energy transfer are relevant: i.e., motive forces, gravitational and impaction forces, friction, pressure drop, heat
Product to air interface	Relative extent of interaction of a substance with adjacent air during an activity. This is large if a large fraction of product is in contact with adjacent air, while it is low if only a small fraction is in contact with adjacent air
Scale	Provides information on the total amount of substance available for emission
Emission generation mechanism	This is a pragmatically described mechanism by which a particular type of energy (see above) leads to release of a substance into the air surrounding the parent material or the surface to which the substance was attached
Activity	Activity is defined as a specific delimited process step with handling characteristics that differentiate it from other process steps
Process	A process is, in this scope, a combination of activities that leads to a required end result. An example of a process is e.g. 'producing a batch of adhesives'
Activity class	Generic groups of activities with similar underlying determinants for activity emission potential
Product	A chemical product, consisting of either a pure chemical component or a mixture of ingredients where the function of the product is not largely governed by its shape: e.g. a powder, granule or pelletized product or a liquid.
Solid object	A solid form, consisting of one or more chemical components, whose function is largely governed by its shape

A successful classification system will have the following necessary characteristics:

- All activities in an Activity Class must be capable of being modeled using the same underlying determinants for activity emission potential.
- An activity can only be assigned to one Activity Class.
- The number of Activity Classes should be much less than the number of activities to be clustered.

It is important to note here that an Activity Class is not a group of activities with similar exposure levels, comparable to the so-called homogeneous exposure group concept (Rappaport, 1991). Emission rates and exposure levels within an Activity Class can be very different, but the influence of the activities on emissions within one Activity Class can be described by a unique set of determinants. For example, dumping 1 kg of powder or 1000 kg of powder are in the same Activity Class, while these activities would clearly lead to different exposure levels.

The clustering of activities into a limited number of Activity Classes is based on two main components: i) the type of emission generation mechanism and ii) the physical state of the product handled during an activity (solid, liquid). The combination of these components enables a structured distinction between types of activities in terms of their underlying exposure determinants. 'Emission generation mechanism' is a pragmatically described mechanism by which a particular type of energy transfer (as described in Tielemans *et al.*, 2008a) leads to release of a substance from the parent material or the surface to which the substance was attached. The various emission generation mechanisms will be discussed in the following section. Details of the derivation of Activity Classes will be given in a subsequent section.

2.4.4 Emission generation mechanisms and parameters of amount of energy transferred

A number of emission generation mechanisms have been distinguished by the authors. A recent publication by the UK Health and Safety Executive (HSE, 2008) describes "common processes and sources" of airborne contaminants. These processes were taken as starting point and modified, clustered or extended where considered relevant. The determinant of activity emission potential "amount of energy transferred" is closely related to the emission generation mechanisms involved. Therefore, for each emission generation mechanism the specific parameters that are considered to be useful and practical for assessing in an activity are presented as well. The relation between emission generation mechanisms and Activity Classes is given in Table 2.4.2.

Pressure difference

Pressure difference is the driver of and main type of energy transfer involved in the emission of liquids and solids in spray processes. Pressure difference can also be used as specific parameter for assessing the amount of energy transferred. For spray application this parameter can be expressed as 'spray pressure' (Carlton and Flynn, 1997; Brouwer *et al,*. 2001; Tricou and Knaziac, undated).

Evaporation

Evaporation is a major mechanism by which liquid substances are emitted into the air surrounding the liquid. The rate of evaporation generally depends on the (partial) vapour pressure of the substance under the conditions of use. The partial vapour pressure of a substance is influenced by the temperature of the product and its composition. The basic type of energy transfer for this emission generation mechanism is therefore 'thermal energy' and the temperature of a liquid product at the site of emission is therefore a parameter of amount of energy transferred. In case that evaporation occurs in an enclosed system, a secondary mechanism 'displacement' may play an important role as well. This is the action where a volume of air is forced out of a containing system and is relevant only after evaporation has taken place.

Table 2.4.2 Activity classes, activity subclasses and emission generation mechanisms

Activity class	Description	Activity Subclasses	Emission generation mechanism(s)	Example activities
Exposure to substances that are part of or adhere to a solid object1)				
Fracturing and abrasion of solid objects	Activities where solid objects are broken into smaller parts or are abraded due to frictional forces.		1. Crushing 2. Impaction 3. Abrasion	Crushing concrete, Jack hammering, Pulverizing, Sawing using a circular saw, (Manual) milling, Sanding, (Cut-off) grinding of steel, Drilling, Buffing, Polishing, Chiselling, Cutting, Logging, Demolishing with wrecking ball, Wrecking, Shredding of batteries, Wire drawing, Cold rolling of metal sheets
Abrasive blasting	A surface preparation technique for removing coatings or contamination by propelling abrasive material towards the surface at high velocity. ART only considers exposure arising from the surface coatings during abrasive blasting (i.e., exposure to the abrasive material is not included)		1. Abrasion 2. Pressure difference	Grit blasting, (Ultra) high pressure blasting for stripping paint, Water cutting
Impaction on contaminated solid objects	Activities where impaction or striking of a tool on an object contaminated with powder or granules potentially results in re-suspension of that powder. For this activity class, exposure is estimated to be related to the level of contamination on the surface or the object that is impacted on.		1. Impaction	Hammering, Nailing, Piling. Punching
Exposure to substances that are part of or adhere to a powder, granule, or pelletized material1)				

Activity class	**Description**	**Activity Subclasses**	**Emission generation mechanism(s)**	**Example activities**
Handling of contaminated solid objects or paste	Handling or transport of surfaces, objects or pastes that are (potentially) contaminated with powders or granules. For this activity class, exposure is estimated to the contamination on the surface, object or paste.		1. Movement	Sorting, Stacking, Carrying, Picking / collecting objects, Packaging, Paving, Wrapping, Disposal of empty bags, Plastering, Kneading, Modelling of product, Bending metal tubes
Spray application of powders	Spraying activities used to intentionally disperse powders on surfaces by using a pressure difference.		1. Pressure difference 2. Impaction	Dusting crops, Powder coating, Spraying of concrete
Movement and agitation of powders, granules or pelletized material	Activities where movement and agitation of powders results in disturbances of the product causing dust particles to become airborne.		1. Movement 2. Agitation	Sweeping, Application of compressed air, Vacuum cleaning, Mixing, Weighing, Raking, Sieving
Transfer of powders, granules or pelletized material	Activities where a stream of powder is transferred from one reservoir (or container, vessel) to the receiving vessel. The product may either fall due to gravity from a high to a lower point (dumping of powders), be transferred horizontally (scooping of powders) or is transferred through a hose or tube with pressure (vacuum transfer).	Falling of powders, granules or pelletized material	1. Gravitation 2. Impaction	Bagging solids, Dumping solids in mixers, Loading barges with minerals or cereals, Scooping, Scattering, Filling of bottles
		Vacuum transfer of powders, granules or pelletized material	1. Pressure difference 2. Impaction	
Compressing of powders, granules or pelletized material	Activities where powders, granules or pelletized material are compressed due to compaction or crushing.		1. Crushing 2. Impaction	(steam)Rolling, Compacting, Tabletting, Granulation, Pelletization
Fracturing of powders, granules or pelletized material	Activities where powders, granules or pelletized material are crushed and broken into smaller parts or sizes due to frictional forces (e.g. between two surfaces or objects)		1. Crushing 2. Impaction 3. Abrasion	Grinding minerals, Milling cereals, Very small scale crushing, Testing tablets, De-lumping (breaking up products), Large scale bulk milling
Exposure to substances that are part of or adhere to liquid products				

Activity class	**Description**	**Activity Subclasses**	**Emission generation mechanism(s)**	**Example activities**
Spray application of liquids	Activities used to atomise liquids into droplets for dispersion on surfaces (surface spraying) or into air (space spraying). Spraying techniques may be used for dispersion of e.g. pesticides, biocides, and paints.	Surface spraying of liquids	1. Pressure difference 2. Evaporation 3. Impaction	Spray application of paints on e.g. ships (using HVLP or airless techniques), Pest control operations (using backpack), Spraying cleaning agents onto surfaces, Foaming, Tractor mounted spraying
		Spraying of liquids in a space	1. Pressure difference 2. Evaporation	Spraying room deodorizers or fragrances, Fogging, Fly spray
Activities with open liquid surfaces and open reservoirs	Handling of a liquid product in a bath or other reservoir. The liquid may either be relatively undisturbed (e.g. manual stirring, dipping in bath) or agitated (e.g. gas bubbling, mechanical mixing in vessel).	Activities with relatively undisturbed surfaces	1. Evaporation	Dipping objects in a cleaning bath (where the presence of treated surfaces in the area is limited), Immersion of objects, Manual stirring of paint, Tank dipping
		Activities with agitated surfaces	1. Evaporation 2. Agitation	Electroplating, Bath with gas bubbling, Mechanical mixing / blending of paint, Aeration of waste water, Boiling, Shaking liquids (e.g. in chemical laboratories)
Handling of contaminated objects	Handling of solid objects that are treated or contaminated with the liquid of interest.		1. Evaporation	Heat drying tasks, Evaporation from painted surface or object, Maintenance of fuel pumps, Coupling and decoupling of hoses or (drilling) equipmen, Handling of contaminated tools
Spreading of liquid products	Activities where liquid products are spread onto a surface		1. Evaporation	Painting a ceiling and walls with a roller and a brush, Hand lay-up activities with styrene, Pouring a liquid flooring material on a floor, Cleaning of liquid spills, Gluing, Mopping, Embalming, Laminating, Lubricating, Sponging, Screen printing, Cleaning of oil residue from bulk tanks
Application of liquids in high speed processes	High energy activities with e.g. rotating tools where liquids are added to the process (e.g. metal working fluids).		1. Movement 2. Agitation 3. Evaporation	Use of metal working fluids with e.g. circular saws and drills, Centrifuging wet items Press printing

Activity class	**Description**	**Activity Subclasses**	**Emission generation mechanism(s)**	**Example activities**
Transfer of liquid products	Activities where a stream of liquid product is transferred from one reservoir to the next. The stream may either fall or glide from high to a lower point (falling liquids) or is transferred with pressure (pressurized transfer: e.g. bottom loading).	Bottom loading	1. Evaporation	Bottom loading of tanker at bulk terminal, Under wing refuelling of aircraft, Transfer of additives in tanker using bottom loading
		Falling liquids	1. Gravitation 2. Impaction 3. Evaporation	Top loading of tanker at bulk terminal (boats, rail car or truck), Filling of drums, Pouring, Filling of bottles, Filling of paint gun, Refuelling of cars, Manual calibration of fuel pump, Over wing refuelling of aircraft
Burning of liquids[2]	Activities where a liquid product is burned. The process of burning leads to elevated temperatures and to reactions in the liquid as well as in the vapour.		1. Burning 2. Evaporation	Burning of liquid fuel
Exposure to substances that are part of metals or metal products				
Smelting and melting of metal	Activities where metals or products containing metals are heated at high temperatures above their melting point, which makes them fluid.	Smelting of metals	1. Oxidation / burning 2. Convection	Zinc smelting
		Melting of metals	1. Oxidation / burning 2. Convection	Melting in a furnace
Pouring or tapping of molten metal (including melt drossing and dipping in molten metal)	Activities where molten metal is transferred from one vessel in another or where products (e.g. dross) or objects are taken from a molten metal.	Pouring or tapping of molten metal	1. Oxidation / burning 2. Convection 3. Movement	Sand casting. Aluminium permanent mold
		Dipping in molten metal	1. Oxidation / burning 2. Convection 3. Movement	Continuous hot dipping. Galvanizing,
Sintering, roasting and oxidation / burning	Activities in which a metal powder or ore is heated with the result that the powder particles form strong bonds into a solid	Sintering	1. Oxidation / burning 2. Convection	Sintering metal powders into objects

Activity class	**Description**	**Activity Subclasses**	**Emission generation mechanism(s)**	**Example activities**
	objects or metals or contaminants are oxidized	Roasting	1. Oxidation / burning 2. Convection	Roasting metal ores
		Oxidation / burning	1. Oxidation / burning 2. Convection	Burning metal powders (to produce metal oxides)
Spray application of molten metal	Activities in which molten metal is sprayed onto a surface to produce a metal coating		1. Pressure difference 2. Oxidation/ burning 3. Impaction	Flame spraying, Electric arc spraying
Atomisation	Activities in which a molten metal stream is atomized for production of metal powders		1. Pressure difference 2. Oxidation / burning	Atomized metal powder production
Compressing of, impaction on, or hardening of hot metal objects	Activities in which hot metal objects are subjected to a mechanical force to compressed and harden the metal		1. Impaction 2. Oxidation / burning 3. Convection	Hot rolling, Hot forging

1) Similar Activity Classes (and Activity Subclasses) can also be developed for fibrous objects and products, e.g. ‘Handling of fibrous objects’ in which ‘Sorting of textiles’ would be an example activity. However, the present version of ART does not include exposure to fibers yet.

2) This Activity Class is not yet included in ART. Similar Activity Classes can be developed for burning of solid objects and burning of solid powders.

Evaporation is generally not an important emission generation mechanism for solids, except for emission of substances from molten solids into the air. For these situations, the specifics of the technique influence the temperature of the product and this again influences the partial vapour pressure of the substances in the product. These factors were found to influence e.g. fume emissions in welding (Dennis *et al.*, 2001). Air currents (thermal convection) caused by heat from the molten materials further increase emissions. Because the temperature at the melt and the related 'vapour pressure' of the substance at that temperature will generally not be known, a proxy is proposed. This proxy is based on the differentiation between techniques (e.g. different welding techniques such as manual metal arc welding, tungsten inert gas welding, etc.) and between the materials handled (e.g. stainless steel, aluminium, different polymers). In reality this implies that generic modeling of emissions as a result of this generation mechanism is very difficult for solids.

Emission due to evaporation also depends on the air flow over the evaporating surface. The relative air flow can partly be caused by the activity, e.g. for pouring of liquids. The air flow due to e.g. the ventilation and moving objects in the area is generally not linked to the activity. Due to this mixture of influences, it was decided not to use the (relative) air flow in itself as a determinant of activity emission potential related to evaporation.

Movement

The actual type of energy transfer relevant for the emission generation mechanism 'movement' is the energy transfer involved in overcoming inertia. Inertia is the resistance of an object or a product to a change in its state of motion. Substances in an object or present at the surface of an object may be released when the object's state of motion changes (abruptly). This is relevant in handling of (contaminated) solids such as sorting or stacking.

Movement is often relevant in conjunction with agitation (see next section) in activities with a relatively high level of energy transfer. For example, a fast spinning object may lead to release of substances from its surface when the forces binding the substances to the surfaces are weaker than the effect of inertia. The amount of energy transferred is related to the changes in the movement, which in these activities mostly are directional changes. It is proposed to use a measure of relative 'change of movement' as a proxy determinant for amount of energy transferred. Such a measure can be related to e.g. the number of rotations per minute of a drill that lead to emission of applied metal working fluids.

The main emission generation mechanism in (re)suspension of solids to air due to for instance cleaning activities is also 'movement'. Here the emission is caused by a force that changes the state of movement of substances that were originally at rest in a pile or on a surface. The determinant of amount of energy is again a proxy, with categories based on the combination of the 'technique' or method for producing the (re)suspension and the (re)suspended material. The method that leads to (re)suspension can e.g. be compressed air blowing or brushing and sweeping.

Agitation

Agitation as an emission generation mechanism is very similar to 'movement'. Agitation as intended as principal emission generation mechanism is the acting of motive forces on a product leading to substantial movement in the product, without necessarily a movement of the product as a whole (that is eminent in the emission generation mechanism movement). The agitation may lead to (temporarily) dislodging of substances from surfaces or its parent material. It thereby increases contact with air and hence the possibility for emission. Ultrasonic vibration, shaking of liquid containers, and bubbling of gas through a liquid are all examples of agitation.

Agitation may also lead to movement of air above the product, which increases transport of dislodged aerosols further from the source into the adjacent air. The effect of an agitating force on a product not only depends on the amount of energy applied, but also on the resistance of the product to movement. Therefore, a proxy determinant based on the visible effect of agitation is proposed for amount of energy transferred. A number of categories and related examples can be used to describe the level of agitation (e.g. limited agitation, moderate agitation, and high level agitation).

Gravitation

The influence of gravitation on products results in a stream of powder or liquid that falls or flows from a higher point to a lower point. This stream interacts with air, inducing air currents in and around the stream and release of vapour, dust or droplets from the stream. The friction due to flowing also leads to secondary emission generation mechanisms such as agitation and abrasion. It also induces impaction of the stream at the receiving surface, which again leads to interaction with air and further release of dust or droplets. Impaction is described as a separate emission generation mechanism (see below). When the product fills a container, the secondary mechanism 'displacement' is also relevant. To achieve gravitational transfer, a limited pressure may be used to force the flow of material to the point where the gravitational effect starts. However, this pressure is assumed to be too low to lead to dispersion through air (*i.e.* the product is transferred in a relatively dense stream). The proxy determinant of amount of energy transferred for gravitation is the falling height of the product (Heitbrink *et al.,* 1990, 1992; Cowherd C Jr, Grelinger MA, Wong KF., 1989; Plinke *et al.,* 1991; Wypych *et al.,* 2005).

Crushing

Crushing is the activity where solids are broken into parts by a frictional force exerted by two or more objects. The frictional forces also lead to shear forces in the product or object contributing to the crushing effect. When the product or object is broken into parts, dust particles can be emitted into the air from the product or object or from contaminants attached to an object. The crushing action may also induce an air stream that further increases the emission. The determinant for amount of energy transferred is either the pressure (force) with which objects are forced together or a proxy for the crushing technique (e.g. impactor, jaw crusher, roll crusher, scrap shredder).

Abrasion

Abrasion is the release of substances from solids due to frictional forces. Depending on the techniques and related forces the release of airborne particles, including any contamination (e.g. liquids) on them is possible. The frictional forces can be caused by another object (e.g. a grinding wheel) or by a product forcefully applied to the solid object (e.g. high pressure water jet or grit blast). The amount of energy transferred is determined by factors such as relative speed of surfaces and number of abrasive contact points between the objects (Flynn and Susi, 2003; Hamill *et al.*, 1991). It can be described pragmatically by a proxy based on the abrasive technique and a proxy based on the abraded object material. In this way categories may be defined from limited energy transfer (e.g. manual sawing of wood), through more intensive energy transfer (e.g. belt sanding of wood) to high energy transfer (e.g. milling in a concrete wall or grit blasting).

Impaction

The impaction of solid objects or products onto (contaminated) surfaces can lead to scattering of product into droplets or dust and subsequent emission of aerosols. Such impaction can be caused by gravitation, by spray dispersion or by forced motion of the surface (of an object) onto another object (e.g., hammering). The speed at collision influences the emission. The speed of a solid object driven into or onto another object can be known and can be used directly as a determinant. For spray applications the speed at collision depends on the pressure difference and the distance between nozzle (point of departure) and surface (point of impact). For falling powders or liquids the dropping height is relevant.

Burning / oxidation
Burning of products (e.g. gasoline) or solid objects (e.g. logs of wood) leads to the release of substances from the products or objects. The burning action breaks binding forces between parts or substances and the heat of burning results in a substantial air flow from the hot material, taking any light solid particles, liquids and gases with it. Burning often results in substances being emitted that are different chemicals from those in the solid object, due to the chemical reactions taking place. Further reactions take place between substances/particles and components of the air. However, burning is not always complete and it therefore often also leads to substantial emission of original components. The roasting of metal ores and the production of metal oxides by melting at very high temperatures is considered also to be a form of 'burning' in the scope of this paper.

Burning is usually the result of chemical processes releasing energy in combination with an ignition source and sufficient availability of oxygen. There is no easy parameter for amount of energy transferred in this Activity Class. Therefore, it is proposed to again use a proxy based on a combination of the technique used for burning and the material burned in the process. Both factors influence the speed and effectiveness of the burning process, e.g. the control of oxygen addition to the burning process and the temperature of the material. This in turn influences the emission of substances. For the technique a categorisation can be made in e.g. open burning (no control of oxygen flow and flue gas at all), enclosed burning (limited control of oxygen flow and flue gases), closed controlled burning (oxygen flow and flue gas controlled) and specialized burning (e.g. engines of vehicles with high quality control of burning parameters). For the material burned a categorisation can be made in e.g. solid coal-like fuels, wood, refuse, different liquid fuels and metal ores or ingots.

2.4.5 Derivation of Activity Classes and Activity Subclasses

The process of developing Activity Classes and Activity Subclasses was an iterative process. At the start a more or less theoretical approach was followed to propose a set of Activity Classes and Activity Subclasses. The proposed Activity Classes and Activity Subclasses were then reviewed and tested by industrial partners in the project. These partners (IFA, Shell, GlaxoSmithKline and Eurometaux) all tried to fit their activities in the proposed Activity Classes and Activity Subclasses. Where the system was considered not sufficient to fit all activities in an understandable way, the partners suggested changes in the system. Based on the suggestions changes were made. Part of these changes were made to allow better understanding of practical users in industry sectors of the Activity Classes and Activity Subclasses and to allow a better fit with already existing groupings of activities in industry sectors. The final system of Activity Classes and Activity Subclasses as presented here is therefore developed by a mix of theoretical and pragmatic arguments.

The first step in the approach was to derive Activity Classes based on differences in emission generation mechanisms and physical states because this leads to a clear structural distinction between types of activities. In principle, each combination of a separate emission generation mechanism and a separate physical state (solid, liquid, gas) leads to a separate Activity Class. However, some emission generation mechanisms only apply to one physical state, e.g. evaporation, which is generally considered to be only relevant to liquids. Furthermore, each combination of two or more emission generation mechanisms and a separate physical state can lead to a separate Activity Class. However, several theoretically possible combinations of emission generation mechanisms are considered to be logically inconsistent. For example, the emission generation mechanisms crushing and pressure difference are unlikely to occur at the same time in one activity. Those cases will not lead to a distinction in Activity Classes.

In line with this concept, new Activity Classes may be added in the future by making new combinations of emission generation mechanisms and physical states. If necessary, new emission generation mechanisms could also be added in the future.

The determinants product to air interface and scale cannot easily be expressed in the same units for some activities within some of the Activity Classes. For these reasons, Activity Subclasses have been defined for some Activity Classes. In this way for each Activity Subclass one set of similar parameters can be used to assess the activity emission potential.

In the second step of the approach, the review by industry partners, modifications were made partly on theoretical and partly on pragmatic grounds. For instance, the specific activities related to melting, smelting and atomisation of metals were originally considered to fit an Activity Class called 'hot solid handling'. After testing by the metal industry it was decided to create instead a number of 'metal-specific' Activity Classes to allow a better fit to clustering of activities already known in this industry.

The Activity Classes, Activity Subclasses, and examples of allocated activities are presented in Table 2.4.2. A more extended list of activities with Activity Classes and Activity Subclasses is presented on the ART website.

2.4.6 Activity Emission Potential; underling parameters

Source emission is determined by energy transfer (as discussed under emission generation mechanism) and by factors that are related to product-to-air-interface and scale. Product to air interface is the factor that describes the relative contact between a product and the air, while scale describes the amount of product available for emission. These two factors are not always easy to distinguish or to evaluate. Ideally, the result of their effect should be expressed in terms of amounts per unit of time, because they are used to assess emission, e.g. by using 'use rate' (in amount/time) for scale, while using a unitless relative factor for product to air interface.

A pragmatic solution to these problems is to use proxy parameters for scale and product to air interface or for a combination of them and to allocate situations into categories of these proxy parameters. The proxy parameters for scale can be different for different Activity Classes or Activity Subclasses. For activities where there is a clear 'use rate' this parameter can be used as a proxy for scale. This is e.g. possible for application of products onto surfaces, with or without spraying (Bjerre, 1989; Warren *et al.,* 2006; Naidu Potana, 2001; Datar, 2003). The application technique determines the product to air interface, which would e.g. be very high for spraying with small droplet sizes, lower for spraying with high droplet sizes and lower still for rolling and brushing. For transfer activities 'transfer rate' is a form of ' use rate' that can be used as the parameter for scale (Plinke *et al.*, 1991; Wypych *et al.*, 2005; Heitbrink *et al.,* 1992). In these activities product to air interface would be determined by the relative contact with air that the product has during transfer. This would be very high for splash loading or dumping of powders from bags, lower for submerged loading or transfer of powders through pipes and very low for transfer of gases in a closed system (USEPA, 1985; MRI, 1986). A possible unit for scale in filling of containers would be the number of containers times their size, as this determines the amount of contaminated air displaced during the activity.

For activities in which e.g. products or objects are crushed or burned, objects are abraded or solids are melted (partially), the scale may be presented by the amount per unit of time of solids, objects or products transformed. Dennis *et al.*, (2001) e.g. showed that the emission of fumes in welding depended on the surface area of molten metal in the arc wire. The product to air interface in these cases is a unitless factor that indicates how much of the product is in contact with air in these activities. This is generally a proxy that is related to the technique or equipment used. For e.g.

crushing in between two millstones the product to air interface would be low, while for open burning the product to air interface would be high.

In several activities there is basically a fixed amount of product during the activity, e.g. in dipping activities, (re)suspension of solids from surfaces into the air or activities where agitation is the main emission generation mechanism. In these cases there is no clear ‘use rate’. Also, the full amount or volume of a product is not necessarily relevant for emission, because often only substances from a top layer of the product actually can be emitted. Therefore, either no practical parameter for scale can be used or a very specific parameter related to the specific activity can be used, such as ‘level of agitation’ for the Activity Class ‘Movement and agitation of powders, granules or pelletized material’ .

To conclude, as with energy transfer, the allocation of activities to categories of product-to-air-interface and scale will have to be done based on descriptive examples, because a specific parameter is often not available. Proxy parameters related to e.g. technique and surface area can often be used instead. Table 2.4.3 shows the parameters and classes that were finally chosen for use in the tool. Exposure surveys from main occupational hygiene journals were reviewed to provide a benchmark for categorization and scoring of the activity emission potential. In the absence of sufficient ‘hard’ data, expert judgement was used in the process and each categorization was discussed among all members of the ART consortium as well as external experts. The assessment of exposure weights of the activity emission potential as well as other MF of ART is described in detail elsewhere.

2.4.7 Discussion

Hierarchical coding systems are necessary to comprehensively store and classify data according to industry, job title, and activities (Vinzents *et al.*, 1995; ‘t Mannetje and Kromhout, 2003). Standard coding systems for industry (e.g., ISIC) and job (e.g., ILO) are often used, but no international system has been developed for occupational activities (Gomez, 1994). The PROCs developed by ECHA (2010) are an attempt in that direction, but are not yet sufficiently structured and are not fully based on activities related to emission potential. Many large exposure databases therefore fail to code activities or determinants related to activities that are relevant for emission and consequently for exposure. According to Rajan *et al.* (1997), “process” is a data element in the core information on occupational exposure measurements. However, because no coding system was available until now, databases of occupational exposure measurements generally record activities (or similar determinants, such as “processes” or “tasks”) as free text. This leads to multiple terms for the same activity and does not facilitate finding data on the same or similar activities. The Activity Class concept aims to improve this situation.

A workshop on a source taxonomy for consumer exposure modeling defined five so-called ‘bins’ of consumer exposure sources: vapour from dry sources, vapour from wet sources, particulate matter sources, combustion sources and chemical reaction sources (Kephalopoulos *et al*., 2006). Suggestions for modeling approaches for each ‘bin’ were presented, but they were not based on the same structured considerations on emission as the Activity Classes in this paper.

The exposure assessment approaches developed by Cherrie *et al.* (1999) and the Stoffenmanager (Marquart *et al.*, 2008; Tielemans *et al*., 2008b) currently use five generic and broad classes with descriptive examples to quantify the activity emission potential. The presented Activity Class concept facilitates a much more specific and detailed classification scheme for activity emission potential that builds on this previous work. For each Activity Class distinct classes with tailored descriptive examples for the emission potential of an activity can be defined based on a unique set of determinants. This also helps to improve modeling efforts related to emission and it can thereby become an important aspect in the development of advanced exposure assessment models.

Table 2.4.3 Parameters and range of inputs for Activity Emission Potential; the overall score for Activity Emission Potential is calculated by multiplying the scores for separate parameters

Activity Class	**Activity Subclass**	**Parameter**[a)]	**Range of inputs**[b)]
Fracturing and abrasion of solid objects		Type of material	Wood, Stone, Metal
		Type of handling	Several options, including e.g. ‘manual handling’, ‘mechanical pulverization’ and ‘mechanical sanding’, combined with ‘amount’ in one parameter
		Amounts of dust/size of object	Different inputs per product type. Wood: ‘very limited amount of dust’ to ‘large amounts of dust’. Stone: ‘small size objects’ to ‘large amounts or large objects’. Metal: ‘very limited amount if dust’ to ‘small amount of dust’, combined with ‘type of handling’ in one parameter
		Level of containment of the process	‘Handling that reduces contact between product and adjacent air’ or ‘Open process’
Abrasive blasting		Surface area treated	From ‘micro-abrasive blasting’ to ‘Very large surfaces’
		Wet or dry blasting	‘Wet abrasive blasting’ or ‘dry abrasive blasting’
		Direction of blasting	‘Only downwards’, ‘only horizontal or downwards’, ‘any direction (including upwards)’
Impaction on contaminated solid objects		Level of contamination	Several options from ‘impaction on apparently clean objects’ to ‘impaction on substantially and visibly contaminated objects’
		Force of impaction	‘Normal impaction (manual or light mechanical)’ or ‘Heavy mechanical impaction‘
Handling of contaminated solid objects or paste		Level of contamination	Several options from ‘handling of apparently clean objects’ to ‘handling of substantially and visibly contaminated objects’
		Carefulness of handling	‘Careful handling’, ‘normal handling’ or ‘handling that departs from regular work procedures and involves large amounts of energy’
Spray application of powders		Type of application	‘Dusting using blower’ or ‘powder coating’
		Direction of application	‘Only downwards’, ‘only horizontal or downwards’, ‘any direction (including upwards)’
Movement and agitation of powders,		Amount of product	Several options from ‘movement and agitation of < 10 gram’ to ‘movement and agitation of 1000 kg or more’

Activity Class	**Activity Subclass**	**Parameter$^{a)}$**	**Range of inputs$^{b)}$**
granules or pelletized material			
		Level of agitation	‘Handling with low level of agitation’, ‘other handling with high level of agitation’ or ‘application of compressed air’
		Level of containment of the process	‘Handling that reduces contact between product and adjacent air’ or ‘Open process’
Transfer of powders, granules or pelletized material	Falling of powders	Use rate	Several options from ‘transferring less than < 10 gram/minute’ to ‘transferring more than 1000 kg/minute’
		Carefulness of handling	‘Careful transfer’ or ‘routine transfer’
		Drop height	‘Drop height < 0.5 m’ or ‘drop height > 0.5 m’
		Level of containment of the process	‘Handling that reduces contact between product and adjacent air’ or ‘Open process’
	Vacuum transfer of powders	Use rate	Several options from ‘transferring less than < 10 gram/minute’ to ‘transferring more than 1000 kg/minute’
		Level of containment of the process	‘Handling that reduces contact between product and adjacent air’ or ‘Open process’
Compressing of powders, granules or pelletized material		Use rate	Several options from ‘compressing less than < 10 gram/minute’ to ‘compressing more than 1000 kg/minute’
		Level of containment of the process	‘Handling that reduces contact between product and adjacent air’ or ‘Open process’
Fracturing of powders, granules or pelletized material		Use rate	Several options from ‘fracturing less than < 10 gram/minute’ to ‘fracturing more than 1000 kg/minute’
		Level of containment of the process	‘Handling that reduces contact between product and adjacent air’ or ‘Open process’
Spray application of liquids	Surface spraying of liquids	Use rate	From ‘very low application rate (< 0.03 l/minute)’ to ‘high application rate (> 3 l/minute)’
		Direction of application	‘Only downwards’, ‘only horizontal or downwards’, ‘any direction (including

Activity Class	**Activity Subclass**	**Parameter[a)]**	**Range of inputs[b)]**
			upwards)’
		Spray technique	‘Spraying with no or low compressed air use’ or ‘Spraying with high compressed air use’
	Spraying of liquids in a space	Scale of application	‘Small scale space spraying’ or ‘large scale space spraying’
Activities with open liquid surfaces and open reservoirs	Activities with relatively undisturbed surfaces (no aerosol formation)	Open surface area	From ‘open surface < 0.1 m^2’ to ‘open surface > 3 m^2’
	Activities with agitated surfaces	Open surface area	From ‘open surface < 0.1 m^2’ to ‘open surface > 3 m^2’
Handling of contaminated objects		(Contaminated) surface area	From ‘activities with treated/contaminated objects (surface < 0.1 m^2)’ to ‘activities with treated/contaminated objects (surface > 3 m^2)’
		Level of contamination	From ‘Contamination < 10% surface’ to ‘Contamination > 90% surface’
Spreading of liquid products		Scale of application	From ‘Spreading of liquids at surfaces or work pieces < 0.1 m^2 / hour’ to ‘Spreading of liquids at surfaces or work pieces > 3 m^2 / hour’
Application of liquids in high speed processes (e.g. rotating tools)		Scale of application	‘small-scale activities involving high speed movements’ or ‘Large-scale activities involving high speed movements’
		Level of containment of the process	‘Handling that reduces contact between product and adjacent air’ or ‘Open process’
Transfer of liquid products	Bottom loading	Use rate	From ‘transfer of liquid product with flow of < 0.1 l/minute’ to ‘transfer of liquid product with flow of > 1000 l/minute’
	Falling liquids	Use rate	From ‘transfer of liquid product with flow of < 0.1 l/minute’ to ‘transfer of liquid product with flow of > 1000 l/minute’
		Level of containment of the process	‘Handling that reduces contact between product and adjacent air’ or ‘Open process’
		Type of application	‘Submerged loading, where the liquid dispenser remains below the fluid level’ or ‘splash loading, where the liquid dispenser remains at the top of the reservoir’

Activity Class	**Activity Subclass**	**Parameter**[a]	**Range of inputs**[b]
Smelting or melting of metal	Smelting of metal	Type of application	‘Smelting in an inherently closed process’ (only option at the moment)
	Melting of metal	Scale of application	From ‘very small scale melting (< 100 kg)’ to ‘large scale melting (> 10 tonnes)’
Pouring or tapping of molten metal (including melt drossing and dipping in molten metal)	Pouring or tapping of molten metal	Scale of application	From ‘very small scale pouring or tapping (< 100 kg)’ to ‘large scale pouring or tapping (> 10 tonnes)’
	Dipping in molten metal	Open surface area	From ‘open surface < 0.1 m^2’ to ‘open surface > 3 m^2’
		Protective layer	‘Use of flux as protective layer on molten metal’ or ‘no use of flux’
Sintering, roasting, oxidation or burning	Sintering	Scale of application	From ‘very small scale sintering (< 100 kg)’ to ‘large scale sintering (> 10 tonnes)’
	Roasting	Scale of application	From ‘very small scale roasting (< 100 kg)’ to ‘large scale roasting (> 10 tonnes)’
		Level of containment of the process	‘Enclosed roasting furnace’ or ‘tunnel oven’
	Oxidation, burning	Scale of application	From ‘very small scale oxidation, burning (< 100 kg)’ to ‘large scale oxidation, burning (> 10 tonnes)’
Spray application of hot metal		Scale of application	‘Deposition rate < 5 kg/hr’ or ‘deposition rate > 5 kg/hr’
Atomisation[c]			
Compressing of, impacting on, or hardening of metal objects		Type and scale of application	‘Manual forging, small scale mechanical rolling, or quenching of smaller sized hot metal objects’ or ‘Mechanical hot forging, hot rolling or quenching of large scale metal objects

[a] Parameters are presented in ART in the form of questions. In some cases questions contain more than one parameter, for example in the case of ‘Fracturing and abrasion of solid objects’.

[b] In some cases the input options are presented in an abbreviated form.

[c] For atomisation there are no parameters. Atomisation is always considered to be done in enclosed tank and there is just one score.

For instance, distinct classes for activities in the Activity Subclass ‘ Falling of powders’ can be based on drop height and use rate, whereas open surface area (in contact to air) is an important determinant of exposure potential in ’Activities with open liquid surfaces and open reservoirs’. Further detail on the specific categories describing activity emission potential for each Activity Class are documented in the scientific report on the mechanistic model of ART that can be found on the ART website (www.advancedreachtool.com). This approach is part of the Advanced REACH Tool project (Tielemans *et al*., 2007).

In the process of developing the Activity Class concept some stakeholders were asked to try to allocate their activities into the system that was already partly filled with activities by the authors of this publication. This resulted in a number of modifications, e.g. the adding of specific Activity Classes and Activity Subclasses for activities with (hot) metals. Also, this largely increased the number of allocated activities as presented in the Appendix. The appropriateness of the concept and of the scores chosen has been partly shown by the calibration process in which exposure levels are linked to final ART scores. Due to the fact that the final score is built from scores for several modifiers, this calibration process cannot directly validate the scores for activity emission potential. There is too limited useful measured data available to allow a specific validation of the activity emission potential scores. The final test of the approach will be the use in practice by exposure assessors in the scope of e.g. Chemical Safety Assessment under the REACH regulation. Feedback from this practical use can be used in the future to further improve the system.

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CHAPTER 3

CHARACTERIZATION OF PRINCIPAL MODIFYING FACTORS

3 Characterization of principal modifying factors

3.1 Introduction

3.1.1 Assignment of scores

In chapter 3 a further characterization of the principal modifying factors (MF) is given. We used various sources of information to assess exposure weights for the MF in the algorithm. The assessments are as much as possible underpinned by 'first principles' such as simulations based on physical laws (e.g. mass balances) and knowledge on substance behaviour (e.g., Henry's law). In addition, we compared empirical data from exposure surveys and intervention studies to generate weights for the different classes. An evidence database (ECEL) is built that collates information from the literature on efficacy of various risk management measures (RMM) (Fransman et al., 2008). This ECEL database includes information from approximately 100 publications describing workplace intervention studies and is used to assess exposure weights for various MF (localized controls, segregation, and separation). Exposure surveys from main occupational hygiene journals were reviewed to provide a benchmark for categorization and scoring of the principal MF activity emission potential. An overview of sources used for the various MFs is given in Table 3.1.1.

Table 3.1.1 Overview of principal MF and information sources used to assign exposure weights.

Principal MF	**Source of information**
Activity emission potential	Exposure data from calibration database; literature data; expert judgement
Substance emission potential	'First principles' with respect to physico-chemical properties
Localized control	ECEL-database; expert elicitation workshop
Segregation	ECEL-database; expert judgement
Dispersion	Simulation with two-component box model
Separation	ECEL-database; expert judgement
Surface contamination	Expert judgement
RPE	BSI
Personal behaviour	Expert judgment. This MF could not be quantified in a generic manner and was therefore omitted from the mechanistic model

In the absence of sufficient 'hard' data, expert judgement was also used to assign exposure weights. Hence, the whole rating process relies on both 'hard' and 'soft' information that was discussed and implemented in subsequent and iterative phases. A first assessment was done by researchers from TNO (WF, ET) and IOM (JWC, MvT). Each draft exposure weighting process for a particular MF was discussed among all other members of the ART consortium and modified where necessary. Subsequently, documents were peer reviewed by independent, leading experts from industry, research institutes and public authorities. The list of experts is given in chapter 3.11. In addition, several workshops with experts were organised to discuss the proposed exposure weights for different MF. Based on this comprehensive peer review process a consensus view was developed, resulting in final exposure weights for all principal MF as described in this chapter.

3.1.2 Scope of chapter

The nine MF as proposed in the conceptual model will be discussed in separate paragraphs. First, the MFs reflecting the source component of the model will be discussed: i.e., activity emission potential and intrinsic emission potential. Subsequently, the other MF will be discussed that are related to transport of the contaminant, loss of contaminant due to sinks and uptake by the receptor.

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3.2 Substance emission potential

3.2.1 Definition

The principal MF 'substance emission potential' determines the intrinsic emission potential of a substance. A product can generate exposure due to evaporation or due to release of aerosols. Depending on the type of product and the way it is handled, release of a contaminant may occur in different forms (e.g., vapours, dusts). In line with this observation different features of a substance or product are relevant in terms of emission, such as vapour pressure, dustiness, etc. A systematic classification system would help to transparently classify 'substance emission potential' and take account of the appropriate underlying determinants. Such a scheme for further characterization of 'substance emission potential' is proposed based on type of product and type of exposure that is the result of handling this product. For instance, a solid object may result in inhalable dust exposure due to abrasion or fumes due to hot work. Both situations require a different modelling of 'substance emission potential'. The description of the various exposure forms is provided in chapter 2.3.

For each category proposed in Table 2.3.1 a distinct (set of) underlying determinants should be used for modelling 'substance emission potential'. The nature of the determinants across categories is very different; for liquids a well defined and intrinsic property like vapour pressure is relevant, whereas a less clearly defined and non-intrinsic feature as dustiness has to be used for powders. Hence, the modelling of the MF 'substance emission potential' will be very different for the various categories. A further quantification of 'substance emission potential' for each category will be described below.

3.2.2 Handling solid objects resulting in dust exposure

Almost no literature is available describing intrinsic properties of solid material that determine dust release during abrasive techniques, because emission rate due to abrasive techniques is considered to be mainly determined by the activity emission potential (described in chapter 3.3) and not by intrinsic properties of the material that is abraded. A few studies touch upon this topic with respect to handling wood and stone and some indications exist that 'hardness' of the material is important. Yet, study results with respect to hardness of material are not consistent. Alwis *et al.* (1999) stipulate that hard wood produces more and finer dust than soft wood as a result of the fact that cells are more tightly bound. Alternatively, Thorpe and Brown (1995) showed that harder woods produced a lower rate of dust production rate and finer dust during sanding operations. Chung et al. (2000) did not show any significant differences in the quantity of dust generated from sawing different types of hardwood, softwood or MDF boards. According to Kalliny et al. (2008) processing of hardwood and mixed woods generally were associated with higher exposure than were softwood and plywood, although results may have been confounded by other exposure determinants not accounted for. Petavratzi *et al.* (2007) indicate that hardness of material could be an important factor in dust liberation mechanisms in quarry operations. The importance of hardness was also suggested by Roberts (1997) in her evaluation of dustiness of sandstone, indicating that hard sandstone may produce higher exposures than stone with lower crushing strength. A preliminary study of particle formation upon high speed grinding showed that ultra fine particles are generated by a variety of substrates. Grinding of wood clearly produced aerosols of a larger size distribution as compared to the other investigated (and harder) substrates (i.e., aluminium, steel, ceramic, granite) (Zimmer and Maynard, 2002). However, for modelling purposes we envisage a combination of the substance emission potential and activity emission potential for abrasive techniques with solid objects as is described in chapter 3.3.

The interaction of forces holding particles together (binding forces) and the processes available to separate particles are very important in relation to the dustiness of a substance (Plinke et al., 1995). This is also the case for dustiness evaluation of solid objects, although binding forces are obviously much stronger than for powders. Solid objects may only become dusty due to abrasion as a result of strong frictional forces, which is described in the chapter on activity emission potential (Chapter 3.3). The structure, friability or hardness of the solid material will have an impact on the binding forces of solid objects.

As there is very limited exposure information with respect to the impact of the type of material on exposure levels, we propose to calibrate the model for separate categories with relatively homogeneous intrinsic properties: e.g. 1) rock, concrete, 2) metal, 3) wood, 4) plastic, 5) glass. This highly depends on the available exposure measurement data on different types of material. Hence, we suggest that no relative scoring system for intrinsic emission potential of solid objects is needed (nor possible in this stage) and that this is covered in the activity emission potential scoring (Chapter 3.3).

Increasing the moisture content or adding other additives to a solid object can reduce exposure potential. Water may have been added before handling the product or during handling. The latter is taken into account in the principal MF “localized control’, whereas the former is considered an intrinsic property of the material. We propose three categories of moisture content (Table 3.2.1). Some moisture (5-10 % moisture content) in or on the objects is assumed to be associated with an exposure reduction of a factor of 3. This reduction factor is substantiated by median efficacy values obtained for ‘wet suppression’ (Fransman *et al*., 2008) and exposure reduction figures described for spraying of bricks with a fine water mist (Buringh *et al*., 1990). Increasing the moisture content may introduce reduction of dustiness of one order of magnitude or more (Leith, 1990), and thus a reduction factor of 0.03 is adopted in the proposed scheme for solid objects with a moisture content of greater than 10 %. Nevertheless, the relation with moisture is much more complicated and varies for different types of chemicals.

Table 3.2.1 The effect of moisture content on dustiness of solid objects

Category	Relative score
Dry product (< 5 % moisture content)	1.0
5 – 10 % moisture content	0.3
> 10 % moisture content	0.03

Furthermore, it is assumed that the emission that results from activities with solid objects is linearly related to the weight fraction of the substance of interest in the solid object. For instance, if a piece of wood is coated with a paint containing 10% of a certain chemical substance, it is assumed that when sanding that piece of wood, the emission of that chemical substance is 0.1 times the total emission that arises from that process. This is based on the (worst case) assumption that only the coating with the chemical substance is removed and not the solid object on which the coating is applied (wood , stone, metal, etc.).

3.2.3 Handling powders and/or granules resulting in dust exposure

In this section some background will be given on the concepts of dustiness testing, underlying parameters of dustiness, and the relevance of qualitative classification schemes used in various tools. This category also includes pastes, slurries, and clear soaked wet powders (not containing volatile liquid components) that are contaminated with powders or granules, in which case it is assumed that exposure to the paste or slurry itself can be neglected and exposure to the powdered contamination is assessed.

3.2.3.1 Dustiness testing

Dustiness is an important parameter that is characterized as the propensity of materials to produce airborne dust during handling (Mark, 2005). It is a relative term and the measurements obtained for a given material will depend on the apparatus used, testing time, the mass of the chemical tested, the influence of environmental conditions and the dust fractions measured (CEN, 2006; Mark, 2005; Chung and Burdett, 1994; Breum, 1999). Hence, dustiness is not a well defined physical or chemical property of a product (Lidén, 2006).

Dustiness may be measured by two methods, the rotating drum test and the continuous single drop test (CEN, 2006). The rotating drum dustiness test involves the continuous multiple dropping of a sample of the material in a slow horizontal stream of air, while in the continuous single drop method material is falling through the air into an enclosed chamber. Both methods aim to reliably reproduce the generation of dust under standard conditions. Yet, no single test is likely to be representative of all conditions relevant at the workplace, which means that there is no single ‘right’ test (Lidén, 2006). The two test methods do not always rank materials in the same order and users should therefore choose the method that is most appropriate for the material and handling process they wish to simulate (CEN, 2006).

Dustiness test results can vary substantially between materials. Hjemsted and Schneider (1996) showed that rotating drum dustiness test results varied substantially between 31 different products, i.e. by a factor of approximately 2000. In a EU funded project (SMT4-CT96-2074), 12 different materials were tested using the rotating drum; results showed a factor of more than 50 for inhalable dustiness mass fraction. A much larger sample of 135 different materials showed a factor of 6000 between minimum and maximum dustiness as tested by the continuous drop method.

Relating dustiness test results to ‘real world’ worker exposure is not straightforward. Although these tests have proved useful for ranking materials in terms of dustiness, there have been problems in relating dustiness to either the levels of dust emitted in a handling process or to the exposure of workers (Petavratzi *et al.*, 2007). Heitbrink *et al.* (1990) found varying correlations between dustiness test results and exposure measurements at four workplaces with bag filling and dumping operations. On the other hand, simulations of handling small volumes of powder showed that dustiness index was one of 5 parameters significantly related to exposure (Cowherd et al., 1989). Brouwer *et al.* (2006) showed that dustiness test results could explain ~70% of personal dust exposure variances under controlled circumstances. However, they investigated only a limited number of substances.

The dustiness test determines dust generation per weight of material during a “reference activity” defined by the test apparatus and test conditions. Hence, use of dustiness test results as a proxy for the ‘intrinsic emission potential’ should be explored further under field conditions considering the fact that a dustiness test result is determined by both the specific test activity and the intrinsic emission potential.

3.2.3.2 Underlying determinants of dustiness

Dustiness of powdered, granular, and pelletized materials has been and is studied extensively. However, Hjemsted and Schneider (1996) conducted a comprehensive review and showed that results of studies are sometimes ambiguous, which hampers a firm conclusion. Nevertheless, some general statements can be made and underlying determinants of dustiness are described in Table 3.2.2. Features that may have an impact on dustiness are fraction of fine particles, heterogeneous size distribution, shape of particles, bulk density, moisture, and friability. Yet, the use of simple characteristics like size fraction or moisture for dustiness assessment will inevitably result in substantial misclassification.

Table 3.2.2 The influence of various parameters on dustiness of powdered, granular or pelletized materials

Parameter	Effect
Fraction of fine particles:	Proportion of small particles is important but not the only feature that increases dustiness (Plinke *et al.*, 1992; Mark, 2005). In various studies dustiness does not in all cases increase consistently with increasing fraction of fine particles (Higman, 1986; Upton *et al.*,

	1990).
Heterogeneous size distribution:	Experimental studies show increased dustiness from materials with heterogeneous size distributions compared to monodisperse powders (Upton *et al*., 1990; Plinke *et al*., 1992). An experimental field study showed that presence of wood chips may increase exposure to wood dust (Teschke *et al*., 1994). This may be due to the fact that large particles break agglomerated small particles in the product. For monodisperse powders, agglomerates formed in the bulk will not be broken up by simple handling operations (Mark, 2005). It is, however, unclear what mixture of small and larger particles results in highest dustiness figures.
Shape of particles:	Dustiness may be related to morphology of particles. Irregular and flake shaped particles tend to be more dusty than spherical particles (Hjemsted, 1996; Pujara, 1997).
Bulk density:	Powders with a lower density may be dustier (Cowherd *et al*., 1989), although relationships with bulk density are not very consistent (Mark, 2005).
Moisture content:	Added moisture builds a liquid layer on particle surface and thus increases inter-particle forces. Reduction of dustiness with increasing moisture content is found in different experimental and observational field studies (Alwis *et al*., 1999; Teschke *et al*., 1999; Hjemsted and Schneider, 1996, Plinke *et al*., 1992; Farrugia *et al*., 1989; Westborg and Cortsen, 1990). Moisture effect may vary from one material to the next, depending on the extent that water is absorbed internally or is attached to the surface of particles (Leith, 1991). The relation with moisture is further complicated by the fact that drying may introduce solid interparticle bridges for some substances (Plinke et al., 1995). Other dust suppressants have shown a reduction factor of at least 6 (Breum *et al*., 1999).
Friability of parent material:	Liberation of particles from parent material may increase after prolonged handling of granules or briquettes as a result of attrition (Madsen *et al*., 2004). This implies that dustiness of friable granules may increase with increasing level of energy transferred during an occupational process (Schneider and Jensen, 2008).

3.2.3.3 Dustiness in exposure assessment tools

The parameter dustiness has generally been taken into account qualitatively in exposure assessment tools. Theoretically, a vast range of categories is needed to cover this parameter over the broad range of dustiness scores. Yet, this will confront the users with practical difficulties. Based on experience it appears to be difficult for experts to discriminate between more than approximately five qualitative categories. Therefore, existing exposure models tend to incorporate dustiness in a few relative categories.

For instance, the Stoffenmanager (Marquart *et al*., 2008) model allows classification of products in five dustiness categories. Currently, the dustiness category of substances included in the Stoffenmanager is defined by experts and is primarily based on qualitative terminology related to particle size (solid objects, firm granules or flakes, granules or flakes, coarse dust, fine dust, extremely dusty products) and evaluation of (observed) formation of dust clouds during handling. In this respect, the categorization is a combined effect of substance and activity emission potential. The Stoffenmanager is validated with measurements across a broad range of scenarios, but not all dustiness categories could be covered in this study (Tielemans *et al*., 2008).

COSHH Essentials (HSE, 1999) is an exposure model that uses three dustiness categories to estimate exposure (granules, coarse dust, fine dust). It has been designed to help companies comply with the Control of Substances Hazardous to Health Regulations (COSHH).

Although simple in definition, these qualitative categories may introduce operational difficulties for the user due to their fuzzy boundaries and broad dustiness categories. The categorization process may therefore raise difficulties and introduce 'linguistic uncertainty' (Morgan and Henrion, 1990), in particular if borderline cases have to be evaluated (Tischer *et al*., 2003).

3.2.3.4 Range finding study

A recent TNO range finding study investigated the dustiness of 27 substances. The dustiness of these substances was determined in a rotating drum tester (EDT 38 L; JS Holdings, UK) and the same substances were classified by an expert panel of six occupational hygienists based on the dustiness classifications of Stoffenmanager and COSHH Essentials. Qualitative scores were assigned using a consensus procedure. Spearman correlations (and *P*-values) between measured dustiness for the inhalable, thoracic, and respirable fraction (rotating drum) and qualitative classifications of dustiness are presented in Table 3.2.3. Figures 3.2.1 and 3.2.2 show the association between the inhalable dustiness value, and Stoffenmanager and COSHH classifications, respectively.

Table 3.2.3 Spearman correlation coefficient for dustiness fractions

	Inhalable Spearman's r	**Thoracic Spearman's r**	**Respirable Spearman's r**
Stoffenmanager	0.75 (<0.0001)	0.73 ((<0.0001)	0.66 (0.0002)
COSHH Essentials	0.59 (0.001)	0.60 (0.001)	0.56 (0.002)

Apparently both classification systems have the potential to assess dustiness of a substance, since all correlation coefficients are significant. However, the Stoffenmanager classification system shows better performance than the COSHH Essentials method. Correlation is lower for the respirable fraction when Stoffenmanager is used, while results from COSHH Essentials seem to be comparable across the three size fractions. For both COSHH Essentials and Stoffenmanager, it should be noted that large scattering exists within categories. This is not surprising as dustiness test results cover a few orders of magnitude, whereas the evaluated tools include only three or five categories, respectively.

Based on the relation between median measured dustiness (from the rotating drum tester) and the consensus classification using the Stoffenmanager dustiness parameter (Figure 3.2.1), relative dustiness scores could be derived. The median measured dustiness values were 99, 588, 2933, 8176 mg/kg, for Stoffenmanager classes 'granules or flakes', 'coarse dust', 'fine dust' and 'extremely fine dust' respectively. Unfortunately, 'firm granules or flakes' were not tested. The values correspond to a relative ranking of 0.01 : 0.07 : 0.36 : 1 and could be converted to a log scale: 0.01 (granules or flakes), 0.1 (coarse dust), 0.3 (fine dust), and 1 (extremely fine dust), which appears to be approximately in line with the logarithmic scale of the Stoffenmanager dustiness values (firm granules or flakes (0.01), granules or flakes (0.03), coarse dust (0.1), fine dust (0.3), very fine dust (1.0)). Note that the empirical data deviate from the score for 'granules and flakes' (dustiness test (0.01) vs. score (0.03)). However, the above dustiness test results should be treated as indicative figures as the number of test materials is small and some results are based on only one test run.

Figure 3.2.1 Inhalable dustiness based on rotating drum test for different classifications in Stoffenmanager assessments (white bullets indicate test results based on only one run)

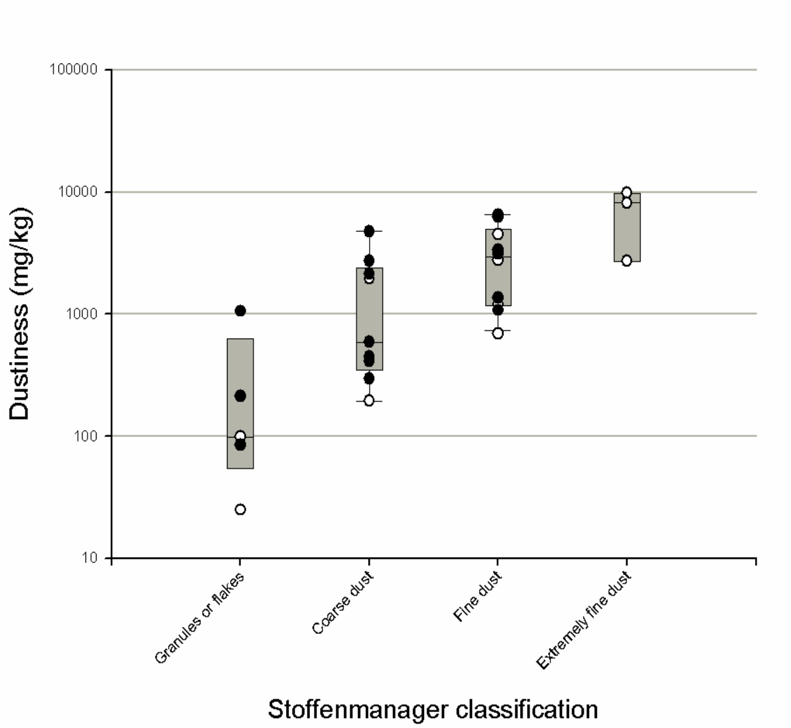
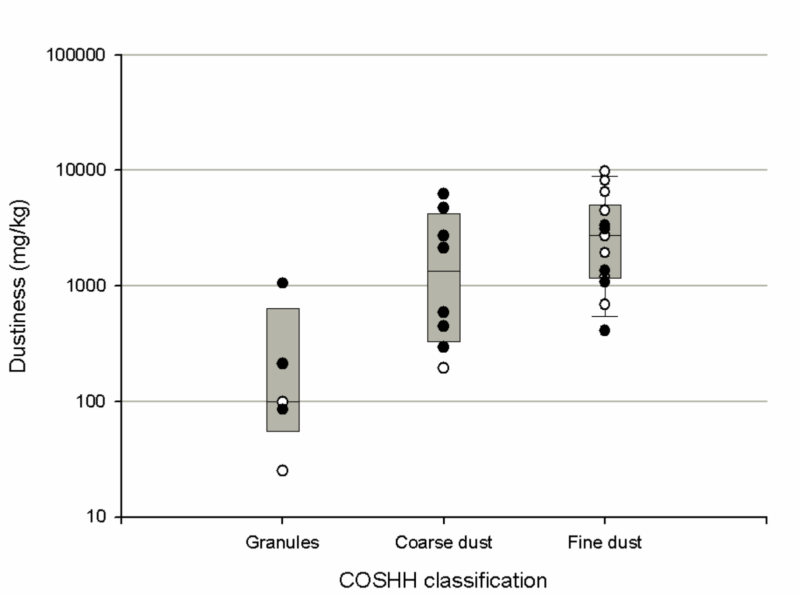


Figure 3.2.2 Inhalable dustiness based on rotating drum test for different classifications in COSHH Essential assessments (white bullets indicate test results based on only one run)



3.2.3.5 Proposal for classification scheme for powdered, granular and pelletized material

Since it will not be feasible to test the dustiness of each and every substance objectively with a dustiness tester, we propose a classification of dustiness on a categorical scale. We propose a scheme similar to the Stoffenmanager classification that makes a distinction into five classes. The classification scheme is shown in Table 3.2.4. The scheme classifies dustiness of dry products and incorporates features like particle size, homogeneous fractions and density in a qualitative, narrative sense. A range of two orders of magnitude between lowest and highest dustiness class appears to be plausible given the total range in individual dustiness test results and the fact that only a limited number of classes are used in this scheme. The classification scheme uses 5 categories as opposed to 4 by CEN. We deviated from CEN in order to increase the resolution of the model. Indicative dustiness test results (based on rotating drum) are provided to give some quantitative insight into category boundaries. However, these indicative values should be treated with great caution, as different test devices produce different results. In case that dustiness test results are available, this information can be used to more accurately assign the relevant scores in ART.

Table 3.2.4 The proposed classification scheme for dustiness categories and assigned values for powdered, granular and pelletized material

Category	**Description**	**Relative score**	**Indicative dustiness test result (inhalable fraction)***	**Indicative dustiness test result (respirable fraction)***
Firm granules, flakes or pellets	Product does not result in dust emission without intentional breakage of products: e.g., firm polymer granules, granules covered with a layer of wax)	0.01	≤ 100 mg/kg	≤ 5 mg/kg
Granules, flakes or pellets	Granules or flakes may fall apart and crumble, resulting in only a very limited amount of fine particles. Handling the product does not result in a visible dust cloud; e.g., fertilizer, garden peat, animal pellets.	0.03	300 mg/kg	15 mg/kg
Coarse dust	A powdered product containing coarse particles. Handling the product in its dry form results in a dust cloud that settles quickly due to gravity: e.g. sand.	0.1	1,000 mg/kg	50 mg/kg
Fine dust	A powdered product containing fine particles. This category may also contain products with a mixture of fine particles and large particles or granules. Handling the product in its dry form results in a dust cloud that is clearly visible for some time: e.g., talcum powder, carbon black.	0.3	3,000 mg/kg	150 mg/kg
Extremely fine and light powder	A powdered product containing very fine, free flowing, light particles. This category may also contain products with a mixture of very fine particles and large particles or granules. Handling the product in its dry form results in a dust cloud that remains airborne for a long time. The product may be wind swept: e.g., magnesium stearate.	1.0	≥ 5,000 mg/kg	≥ 500 mg/kg

* as measured with rotating drum dustiness tester according to CEN (2006)

Increasing the moisture content or adding other additives can reduce exposure potential. Water may have been added before handling the product or during handling. The latter is taken into account in the principal MF “localized control’, whereas the former is considered an intrinsic property of the material. We propose three categories of moisture content (Table 3.2.5). Increasing the moisture content may introduce reduction of dustiness of one order of magnitude or more (Leith, 1990), and thus a reduction factor of 0.1 is adopted in the proposed scheme. Laboratory tests have shown, applying large amounts of water may reduce exposure with approximately 99 percent as compared to baseline (Thorpe *et al.*, 1999). This motivates the introduction of a category with a multiplier equal to 0.01. As described before, clearly (soaked) wet powdered material (like paste or slurry) should not be treated as a powder or granule, unless the paste or slurry is contaminated with a powdered substance. In this case it is assumed that exposure to the paste or slurry itself can be neglected and exposure to the powdered contamination is assessed.

Table 3.2.5 The effect of moisture content on dustiness of powdered, granular or pelletized products

Category	Relative score
Dry product (< 5 % moisture content)	1.0
5 – 10 % moisture content	0.1
> 10 % moisture content	0.01

Furthermore, it is assumed that the emission that results from activities with powders, granules or pelletized material is linearly related to the weight fraction of the substance of interest in the powdered or granulized product. For instance, if a bagging machine is bagging a powder that contains 10% of a certain chemical substance, it is assumed that when handling that powder, the emission of that chemical substance is 0.1 times the total emission that arises from that process.

3.2.4 Handling solid objects or powders resulting in exposure to fumes

This type of emission is outside the applicability domain of the current ART version.

3.2.5 Handling fibrous material

Because we have no exposure measurement data available to calibrate exposure to fibrous material, we decided that this type of emission is outside the applicability domain of the current ART version. However, several experimental studies have been conducted to obtain insight into features of fibrous material that determine its dustiness. Results of these studies have been summarized in Table 3.2.6. Main determinants are the nominal fibre diameter and oil content, whereas coherence and friability of the product may also be important. It is important to note that the relevance of nominal fibre diameter was consistently shown in both experimental and field studies. Esmen *et al.* (1979) produced a simple algorithm to describe the relationship between nominal diameter and fibre exposure.

Table 3.2.6 The influence of various parameters on dustiness of fibres

Parameter	Effect
Nominal diameter of fibres	There is a consistent relationship between decreasing nominal fibre diameter and increasing exposure potential of fibres in experimental and field studies (Esmen *et al*., 1979; Dodgson *et al*., 1987; Schneider *et al*., 1993; Schneider, 1995; Brown *et al*., 1996).
Addition of oil	Adding oil is consistently shown to reduce the fibre emission in experimental studies (average factor 17) and field simulations (average factor 8) (Dodgson *et al*., 1987; Cherrie *et al*., 1987).
Coherence and friability of the fibre product as a whole	Tendency to release fibres will increase with presence of loose fibres or increased friability of fibre products (Class *et al*., 2001).

3.2.5.2 *Proposal for classification scheme for fibres*

In this classification we focus on man-made vitreous fibres (MMVF) and discard natural fibres such as asbestos. MMVF represent noncrystalline fibreous products made from molten glass (fibrous glass), molten rock (rock wool), molten slag (slag wool), or clay (ceramic fibres) (Verma *et al*., 2004). A fundamental property of fibres is their nominal diameter, which is used as the core element in the classification scheme (Table 3.2.7). We used the algorithm of Esmen *et al*. (1979) as a first estimate for relative scores for various nominal diameters. The nominal diameter of fibres in the workplace ranges from less than approximately 1 µm for microfibres, through insulation wools with nominal diameter between 2 and 5 µm, up to continuous filaments with diameter between 10 and 20 µm (Davies and Cherrie, 1992).

Table 3.2.7 Proposed dustiness categories for fibres based on nominal fibre diameter

Nominal diameter (µm)	**Relative score***
0.5	2.8
1.0	1.0
2.5	0.25
7.5	0.05
10	0.03

* Based on Esmen *et al*. (1979)

Adding oil consistently reduces exposure to fibres. An experimental study of Dodgson *et al.* (1987) showed a reduction factor of up to 17. A simulation field study described by Cherrie *et al.* (1987) suggested that these figures may provide an overestimate of the oil factor. Their results show a factor approximately 8. We therefore consider a reduction factor of 0.1 a reasonable reflection of the oil effect (Table 3.2.8).

Table 3.2.8 The effect of adding oil on dustiness of fibrous products

Category	**Relative score**
No oil	1.0
Oil	0.1

3.2.6 *Handling liquid resulting in vapour*

For liquids the process of emission takes place through aerosol formation or evaporation. Evaporation is the change of state of a liquid (or solid) into a gas at the cost of a specific amount of energy. The evaporation rate of a substance depends on the physicochemical properties of the liquid (such as volatility), the dimensions of the source (surface area), and the environmental conditions, such as air temperature, air velocity, direction and turbulence. This section will focus on the vapour pressure as a measure of the volatility and therefore of the intrinsic emission potential of a substance.

When dealing with volatile liquids, vapours and gases it is important to realise the relationships between them. The difference between a vapour and a gas is that, under ambient environmental conditions, a vapour is present in equilibrium with the volatile liquid. The pressure exerted by the vapour in equilibrium with the liquid is known as the saturation vapour pressure. In contrast, for a gas under normal environmental conditions there will be no liquid present. This is because the gas/liquid equilibrium does not exist above the critical temperature (and pressure). This means a gas cannot be compressed to give a liquid without changing the temperature because the critical point (highest temperature and pressure at which a liquid and vapour can co-exist in equilibrium) lies below normal environmental conditions.

Vapour pressure may be expressed in many different units. The most common units are millimetres of mercury (mmHg), atmospheres (atm), Pascal (Pa), bar and pounds per square inch (psi). The SI unit of vapour pressure is the Pa or N m^{-2}. However. pressure is routinely quoted in non-SI units while most thermodynamic equations involving vapour pressure and other thermodynamic parameters use SI units. Therefore it is important to be able to convert non-SI units into SI units and vice-versa. The relationship between these units is provided in Table 3.2.9. Table 3.2.9 (third line) shows, for example, that a pressure of 1 atm is equal to a pressure of 1.013 bar and to a pressure of 14.7 psi. This means that 3 atm of pressure will be equal to 3.039 in bar and to 44.1 in psi.

Table 3.2.9 Units for vapour pressure and conversion factors

	Pa	**bar**	**atm**	**mmHg**	**Ib in^{-2} (psi)**
Pa	1	1.00×10^{-5}	1.01×10^{5}	7.50×10^{-3}	1.46×10^{-4}
bar	1.00×10^{5}	1	0.987	750	14.5
atm	1.01×10^{5}	1.013	1	760	14.7
mmHg	133	1.32×10^{-3}	1.31×10^{-3}	1	0.019
Ib in^{-2} (psi)	6870	0.068	0.068	51.7	1

Lewis (1916) demonstrated that the specific evaporation rate, R_i (mol m^{-2} s^{-1}), of a pure liquid i is directly proportional to the vapour pressure and can be expressed by the general equation for mass transfer given in Equation 3.1 (Nielsen et al., 1995):

$$R_i = k_i(C_i - C_i^{\infty}) \cong k_i C_i = k_i \frac{p_i}{RT} \qquad \text{Equation 3.1}$$

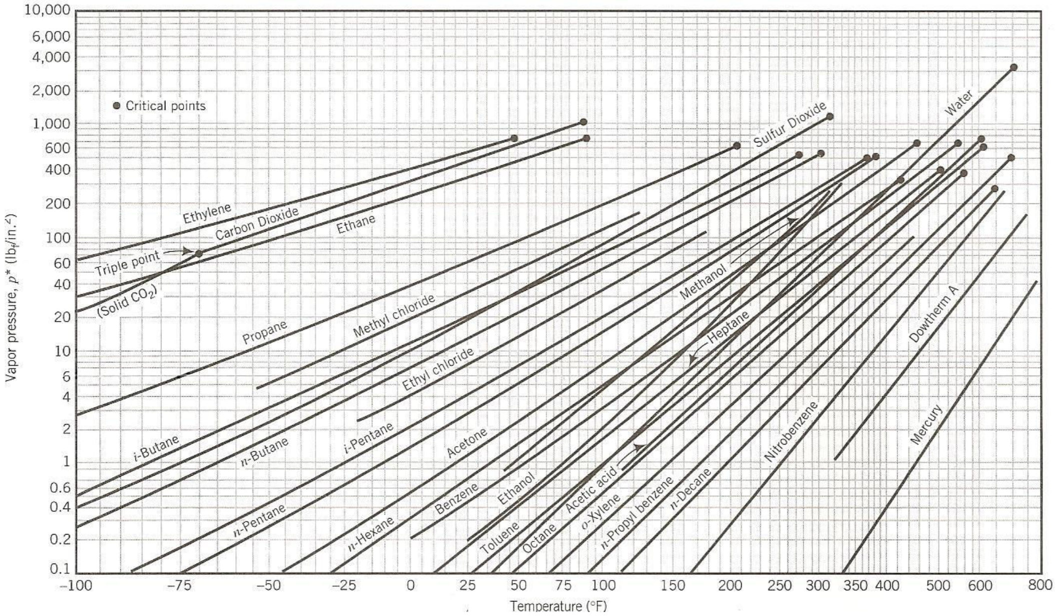
where,

k_i is the mass transfer coefficient (m s^{-1});
C_i is the air concentration of substance i in equilibrium with pure liquid i (mol m^{-3});
C_i^{∞} is the air concentration of substance i in workroom air (mol m^{-3});
p_i is the vapour pressure of substance i (Pa) ;
R is the gas constant (Pa m^3 mol^{-1} K^{-1}); and
T is the liquid temperature (K).

Equation 3.1 shows that the evaporation rate increases proportionally with vapour pressure. This suggests that in conditions if the mass transfer coefficient remains constant, the vapour pressure represents a suitable measure for the substance emission potential. Methods for estimating the vapour pressure for simple single component systems include using empirical correlations, as in the temperature and pressure measurements displayed in a Cox Chart (see Figure 3.2.3), using thermodynamic relationships at equilibrium as in the Clausius-Claperyon equation (Equation 3.3), a derivative of the Clausius-Claperyon employing Trouton's rule (Equation 3.4) and the Antoine equation (Equation 3.5). The applicability and reliability of each of these is discussed below.

The vapour pressure of a substance increases exponentially with the temperature of the liquid. Figure 3.2.3 shows a nearly linear plot of the log of the experimental vapour pressure measured over a broad temperature range for several volatile substances. This type of plot is known as a Cox Chart, after the engineer who developed it in the early 1920s. Example 3.1 explains how to use the Cox Chart.

Figure 3.2.3 Relationship between temperatures (^{o}F) and vapour pressure (lb in^{-2}) for several volatile substances



(Felder and Rousseau, 2000)

Example 3.1: What is vapour pressure of acetone at 150 °C?
As this chart uses °F we first need to convert from °C in into °F. Using Equation 3.2 we can derive that a temperature of 150 °C is equal to 302 °F.

$$T\ (^{o}C) = \frac{T(^{o}F) - 32}{1.8} \qquad \text{Equation 3.2}$$

From the Cox Chart, the vapour pressure of acetone at 302 °F (read off the vertical axis) is about 150 lb in^{-2} which converts to 1.03 $x10^{6}$ Pa (see Table 3.2.9).

The integrated form of the Clausius-Clapeyron equation is given in Equation 3.3:

$$\ln\frac{p_2}{p_1} = \frac{\Delta_{vap}H}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right) \qquad \text{Equation 3.3,}$$

where,

$\Delta_{vap}H$ is the difference in enthalpy between one mole of the saturated liquid and the saturated vapour, or the heat of vapourisation in J mol^{-1};
R is the gas constant, 8.315 J K^{-1} mol^{-1}; and
T is the temperature (K).

This equation can accurately predict vapour pressure over relatively small temperature changes for pure liquids if the heat of vaporisation is known. This is based on some assumptions which fail at high pressures and close to the critical point, namely:-

- The vapour is assumed to behave like an ideal gas

- The enthalpy of vapourisation is assumed to be constant over the temperature range of interest. Changes in $\Delta_{vap}H$ will be small at moderate pressures

An example of how to obtain vapour pressure using the Clausius-Clapeyron equation is given in Example 3.2.

Example 3.2 The $\Delta_{vap}H$ of acetone is 30.2 kJ mol^{-1} at a boiling point temperature of 56 ^{o}C (note that $\Delta_{vap}H$ values may be quoted at 25 ^{o}C or more commonly at the boiling point temperature). What would the vapour pressure of acetone be at 25 ^{o}C?

$$\ln\frac{p_2}{p_1}=\frac{30.2\text{x}10^3\,\text{J mol}^{-1}}{8.315\,\text{J mol}^{-1}\,\text{K}^{-1}}\left(\frac{1}{329\,\text{K}}-\frac{1}{298\,\text{K}}\right)=-1.148$$

$$\frac{p_2}{p_1}=0.317$$

$$p_1=1\,\text{atm (pressure for normal boiling point temperature)}$$

$$p_2=0.317\,\text{atm}$$

Trouton's rule states that the value for the ratio between the enthalpy of vapourisation and the normal boiling temperature (at a pressure of 1 atm) is close to 88 J K^{-1} mol^{-1}, for different liquids. This ratio is the change in entropy of the system, ΔS. Combining the Clausius-Clapeyron equation with Trouton's rule (Horvath, 1992) suggests that the vapour pressure can be approximated by Equation 3.4:

$$\ln p_i \approx -10.6\times\left(\frac{T_{BP}}{T}-1\right) \qquad \text{Equation 3.4}$$

where,

p_i is the vapour pressure (atm);
T_{BP} is the boiling point temperature of the liquid[1] (K); and
T is the temperature of the liquid (K).

Equation 3.4 is a very powerful equation in that it estimates the vapour pressure from only the boiling point temperature of a substance and therefore has great practical use. However, it is equally important to realise it has limitations. The equation is based on the assumption that $\Delta_{vap}H$ is linearly related to temperature between 298 K and the boiling point temperature. The ΔS values for toluene (87.3 J K^{-1} mol^{-1}), benzene (89.4 J K^{-1} mol^{-1}), chloroform (87.9 J K^{-1} mol^{-1}), acetone (88.4 J K^{-1} mol^{-1}), dimethyl ether (88.6 J K^{-1} mol^{-1}) and pyridine (86.3 J K^{-1} mol^{-1}) show that they all obey Trouton's Rule. However overestimation (water, ΔS = 109 J K^{-1} mol^{-1}, and ethanol, ΔS = 110 J K^{-1} mol^{-1}) and in some cases underestimation (indan, ΔS = 56 J K^{-1} mol^{-1}) of the vapour pressure have been reported (Mackay et al., 2002; Olsen et al, 2001). Equation 3.4 is a part of the EUSES software, which is used for risk assessment of new and existing chemicals in the European Union.

An alternative and more accurate method for predicting vapour pressures is the Antoine equation (Reinke, 2000) shown in Equation 3.5 (Felder and Rousseau, 2000):

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[1] http://www.coshh-essentials.org.uk/assets/live/CETB.pdf

$$\log p_i = A - \frac{B}{T + C}$$ Equation 3.5,

where,

T is the temperature (^{o}C);
p_i is the vapour pressure (mm Hg); and
A, B and C are Antoine constants for a given temperature range.

Antoine constants have been estimated for a number of chemicals[2]. It is important to note that the Antoine equation is only applicable to the range of temperatures for which the constants were estimated and to vapour pressures above 0.01 atm. Beyond this range serious errors may occur (Reinke, 2000). Within the stated limits, these methods should provide a reasonably accurate means for estimating vapour pressure for pure liquids. More information can be found in chemical engineering textbooks, such as Lyman (1982).

When estimating the vapour pressure for substances in a mixture one needs to account for the fact that more than one substance will contribute to the overall vapour pressure. This is based on a fundamental thermodynamic relationship called Raoult's law. Raoult's law relates the vapour pressure of the components to their composition in an ideal solution. A correction factor is introduced into Raoult's law so it can be used to find the vapour pressures above non-ideal solutions. This correction factor is called the activity coefficient, γ. It describes how interactions between the components' molecules in solution affect composition (expressed as mole fraction, x_i) and hence the vapour pressure exerted by the components of the mixture. Activity coefficients can be determined experimentally. In addition a computer software tool called UNIFAC is available to estimate the activity coefficients (Fredenslund et al, 1975).

Dalton's law gives the vapour pressure above ideal mixtures of liquids according to Equation 3.6:

$$p_T = \sum_i p_i$$ Equation 3.6

where

p_T is the vapour pressure of the mixture; and
p_i is the vapour pressure of the ith component

Once equilibrium has been attained, the partial vapour pressure of a substance in a mixture, $p_{i,mix}$, can be obtained from Raoult's law (see Equation 3.7):

$$p_{i,mix} = x_i p_i$$ Equation 3.7

where,

$p_{i,\,mix}$ is the partial vapour pressure of the ith component in the mixture;
x_i is the mole fraction of component i in the liquid; and
p_i is the vapour pressure of the ith component when pure.

Consequently, the contribution of the partial vapour pressure of component i to the total vapour pressure of the mixture is reduced as the mole fraction of component i in the liquid phase x_i decreases. This law is strictly valid only for ideal solutions. Examples of two component ideal mixtures are hexane and pentane, or propan-1-ol and propan-2-ol. However in non-ideal mixtures, deviations from this approximation can occur in both directions. This means that vapour pressure can be greater (positive deviations) or less (negative deviations) than that expected to occur under

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[2] http://hl2.bgu.ac.il/users/www/16221/Useful%20data/antoine.html

in ideal solutions. Put generally, when the attractive forces between the molecules in the solution are weaker than the attractive forces between the molecules of the individual components on their own, e.g. ethanol and benzene, there is a positive deviation from Raoult's Law. Negative deviations are found in solutions where the attractive forces between the molecules in solution are stronger than the forces between the molecules of the individual components on their own. An example is nitric acid and water. These deviations can be expressed mathematically by another equation (see Equation 3.8):

$$p_{i,mix} = \gamma_i x_i p_i \qquad \text{Equation 3.8,}$$

where,

$p_{i,\,mix}$ is the vapour pressure of the ith component in the mixture;
γ_i is the activity coefficient of the ith component at a given mole fraction;
x_i is the mole fraction of component i in the liquid; and
p_i is the vapour pressure of the ith component when pure.

When the activity coefficient is unity the solution is ideal and Equation 3.8 reduces to Equation 3.7. If the activity coefficient is greater than 1, then the solution shows a positive deviation from Raoult's law and it as appears as if the solution contains more of component i than that indicated by x_i. Similarly, if the activity coefficient is less than 1, the solution will have a negative deviation from Raoult's law and component i behaves as if there is less of it present than the x_i suggests. There is no single value of γ for a species as activity coefficients are concentration and solvent dependent (Maken S., 2004). Many values for the activity coefficient are listed in data tables at infinite dilution (γ^{∞}), that is where the solution is almost pure solvent with very little solute present (see Table 3.2.10) (Scharzenbach, R. B. et al., 2003). It is at this composition that the activity coefficient for the solute has its maximum value, representing a large deviation from ideality.

Table 3.2.10 Activity coefficients for four solutes at infinite dilution, γ^{∞}, in different solvents

Solute **Solvent**	***n*-Hexane** $\boldsymbol{n\text{-}C_6H_{14}}$	**Benzene** $\mathbf{C_6H_6}$	**Diethylether** $\mathbf{(C_2H_5)_2O}$	**Ethanol** $\mathbf{C_2H_5OH}$
n-Hexadecane $n\text{-}C_{16}H_{14}$	~ 1	~ 1	~ 1	35
Benzene C_6H_6	NA	NA	NA	15
Toluene $C_6H_5\,CH_3$	NA	2	NA	NA
Trichloromethane $CHCl_3$	1.8	0.8	0.3	4.5
Ethanol C_2H_5OH	12	5.4	NA	1
Water	4.6×10^5	2.5×10^3	130	3.6

The data in Table 3.2.10 shows that activity coefficients at infinite dilution are close to 1 where the interactions between the molecules in solution (solute and solvent) are almost the same as those for the molecules of the pure liquid (solute-solute). This is typical of non-polar hydrocarbon solutes mixed with a non-polar hydrocarbon solvent and polar solutes dissolving in polar solvents. The deviation from ideality will increase with increasing differences between the molecular environments of the pure solute compared to that of the solvent. For example the activity coefficient at infinite dilution for ethanol in benzene is about 15. The deviation from 1 is due to the polar interactions of ethanol molecules in the pure form being replaced by other less significant interactions in a dilute solution with benzene. Most organic mixtures tend to deviate from Raoult's law in a positive direction. However Table 3.2.10 shows there are instances where the activity coefficient at infinite dilution is less than one. For example the activity coefficient at infinite dilution is 0.3 for diethyl ether at infinite dilution in trichloromethane. This deviation from unity for activity coefficient at infinite dilution arises from new polar-type interactions becoming available between these components in a mixture that were not present for the two components in the pure form. It has been proposed that the magnitude and direction of the γ^{∞} can be predicted from the differences in polarity between the solute and solvent making up the solution (Popendorf, 2006). However it should be noted that the activity coefficient can be far removed from one e.g. hexane in water has γ^{∞} of 4.6×10^5.

Gmehling et al. (2000) proposed a list (see Figure 3.2.4) of substance classes which can be used in order to determine whether or not the activity coefficients will deviate from unity.

Figure 3.2.4 Substance Classification to estimate the Degree of Non-Ideality in Solutions

Hydrocarbons
Ethers
Aldehydes
Ketones
Esters
Alcohols
Glycols
Water

↓ increasing polarity

Figure 3.2.4 can be used in the following manner. If a solute such as an ether is dissolved in a solvent from an adjacent class (i.e. hydrocarbons or aldehydes) then it is likely that the resulting solution will behave ideally and that the activity coefficient of the solute equals one. If a solute is dissolved in a solvent from a non adjacent class then a large difference in polarity between solvent and solute will lead to non-ideal behaviour and the activity coefficient will deviate from one (hydrocarbon dissolved in water). Therefore the activity coefficient value for a solute will increase with increasing separation between the solute and the solvent class position in Figure 3.2.4. The activity coefficient of most hydrocarbon and other hydrophobic solutes in water will be greater than unity, while the activity coefficient for hydrophilic solutes in water (such as ammonia and formaldehyde) will be less than unity (Popendorf, 2006).

Gmehling et al (2000) proposed a set of pragmatic rules that can be used to estimate the activity coefficients where information on activity coefficient is lacking. These are listed below.

- If liquid components are sparingly soluble in each other then the activity coefficient γ_i can be estimated from the corresponding solubilities

  i.e. s_i = is the maximum solubility of the component i and $\gamma_i = {}^{1}\!/_{s_i}$

  This does not hold for solid or gaseous solutes.

- For mixtures containing solids which do not mix with the solvent then the activity coefficient of the solid can be assumed as 1.
- Values of the activity coefficients for liquids in solutions containing organic solvents appearing in categories adjacent to each other in Figure 3.2.4, range from approximately 1 to 4.

A widely used tool for the estimation of activity coefficients is the group contribution method UNIFAC, which was originally developed by Fredenslund et al (1975). The UNIFAC method considers molecules as assemblies of fractions of molecules (functional groups). Therefore vast number of molecules can be modelled from information on the activities of a limited number of functional groups. A mixture of ethanol and *n*-hexane, for instance, is not considered as a mixture of two molecules (CH_3-CH_2-OH, and CH_3-CH_2-CH_2-CH_2-CH_2-CH_3), but as a mixture of the three functional groups (methyl – CH_3, methylene –CH_2– and hydroxyl –OH.)

In addition to information on the components, UNIFAC also requires information on the mole fraction of the components within the mixture and the absolute temperature of the liquid. An Microsoft Excel computer program for the calculations of the activity coefficients using the UNIFAC method is available for download from the internet[3]. This application will calculate the activity coefficients and partial vapour pressures, based on the molar fraction of the various substances, the temperature and the estimated activity coefficients.

The UNIFAC method for estimation the activity coefficients has several limitations which are listed below:

1) The pressure should be less than 5 bar;
2) The temperature should be less than 150 ^{o}C;
3) Calculations are only applicable to condensable non electrolytes; and
4) Components should not contain more than 10 functional groups.

3.2.6.2 Intrinsic Emission for Volatile Substances

The intrinsic emission potential (E) for volatile substances for ART has been quantified by the intrinsic emission factor (E_i) as defined in the Stoffenmanager exposure assessment tool (Marquart et al, 2007). This factor is directly related to the vapour pressure, measured in Pa, as shown in Equation 3.9:

$$E_i = \frac{p_i}{30{,}000} \qquad \text{Equation 3.9}$$

where,

E_i is the intrinsic emission factor; and
p_i is the vapour pressure in Pa.

The intrinsic emission factor is calculated within the limits of $E_i = 1$ when $p_i > 30{,}000$ Pa and $E_i = 3.33 \times 10^{-4}$ when $p_i < 10$ Pa. Liquids with vapour pressures below 10 Pa mainly lead to exposure based on aerosol release. Liquids with very high vapour pressures above 100,000 Pa behave like gases and should be treated separately.

If the vapour pressure is unknown, as for example in the case of collecting retrospective exposure data for ART or where the mixture composition is poorly defined, then it will need to be estimated using the methods described in previous sections. The following information is needed in order to calculate the partial vapour pressure exerted by a substance in a mixture:-

- The temperature of the liquid (in K);
- The mole fraction of the substance in the mixture (or if the mole fraction cannot be estimated, the weight fraction); and
- The activity coefficient of the substance in the given mixture composition.

As was seen in the previous section, when the vapour pressure of a pure substance at a given temperature is not known, it can be estimated using Equation 3.4 using the actual temperature and the boiling point temperature of the substance. Here, approximations for temperature, mole fraction and activity coefficient values have been presented. This is to enable calculation of the

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[3] http://www.nt.ntnu.no/users/ostvold/SIK3035/info/xlUNIFAC%20Program%20for%20aktivitetsber/?N=D

partial vapour pressure in situations where this quantitative data is lacking. Proposed values for minimum, median and maximum temperatures and mole fractions in several categories are given in Tables 3.2.11 and 3.2.12. Table 3.2.13 provides information on the activity coefficient in terms of several liquid types (products). The approximated activity coefficient and mole fractions can be used with Equation 3.8 in order to obtain the partial vapour pressure of a solution component. Ideally, the activity coefficient and partial vapour pressure values should be obtained using experimental data or from using the UNIFAC model. However, we realise that in many cases this may not be feasible, as the composition of the liquid mixture is not fully known. In this case, we suggest that a default value of 1 is used.

Table 3.2.11 Temperature Categories for estimating Ei

	Temperatures					
	Minimum		**Median**		**Maximum**	
Temperature categories	^oC	K	^oC	K	^oC	K
Below room temperature	0	273	7.5	280.5	15	288
Room temperature	15	288	20	293	25	298
Above room temperature	25	298	37.5	310.5	50	323
Hot processes	50	323	75	373	150	423

Table 3.2.12 Mole (or weight) Fraction Categories for estimating Ei

		Mole fractions	
Mole fraction categories	**Minimum**	**Median**	**Maximum**
Minute	0.0001	0.0006	0.001
Extremely small	0.001	0.003	0.005
Very small	0.005	0.0075	0.01
Small	0.01	0.03	0.05
Minor	0.05	0.075	0.1
Substantial	0.1	0.3	0.5
Main component	0.5	0.7	0.9
Pure liquid	1	1	1

Table 3.2.13 Activity Coefficients Values for estimating Ei

Product	**Activity coefficient**
Pure liquid	1
Liquid solutions	XLUNIFAC (or similar)
Similar (as defined by Figure 3.2.4) organic solvents	1-4
Insoluble solids	1 (for solids)

Sparingly soluble liquids	$\frac{1}{\text{maximum solubility}}$

The partial vapour pressure of the substance of interest can now be estimated using Equation 3.8. The following two examples (3.3 and 3.4) showing how the vapour pressure and intrinsic emission factors can be calculated.

Example 3.3 Consider a hypothetical mixture of toluene and n-butanol at a temperature of 20 °C. The mole fraction compositions are x_{tol}= 0.80 and x_{but}= 0.20 respectively. The vapour pressures are $\overset{\circ}{p}_{tol}$ = 2.9 kPa and $\overset{\circ}{p}_{but}$ =1.7 kPa for the pure substances. The activity coefficients were obtained using the XLUNIFAC model (γ_{tol} =1.11 and γ_{but}=2.48)

The partial vapour pressures are calculated using Equation 3.8:

$$p_{tol} = 1.11 \times 0.80 \times 2.9 = 2.6 \text{ kPa} \quad p_{but} = 2.48 \times 0.20 \times 1.7 = 0.84 \text{ kPa}$$

The intrinsic emission factors are calculated using Equation 3.9.

$$E_{tol} = \frac{2{,}600}{30{,}000} = 0.087 \text{ and } E_{but} = \frac{840}{30{,}000} = 0.028$$

Example 3.4 If the temperature of the same mixture is raised from 20°C to 40°C, then the the vapour pressure for toluene and n-butanol as pure liquids, can be estimated using Equation 3.3. The vapour pressure at 40 °C is found to be approximately 10 kPa, for toluene and is 14 kPa for n-butanol using the XLUNIFAC model. The partial vapour pressures of and the intrinsic emission factors for toluene and n-butanol within the mixture are calculated using Equations 3.8.and 3.9 respectively.

$$p_{tol} = 1.10 \times 0.80 \times 10 = 8.8 \text{ kPa}$$

$$p_{but} = 2.38 \times 0.20 \times 14 = 6.7 \text{ kPa}$$

E_{tol}= 0.29
E_{but}= 0.22

In conclusion, the method chosen for determining the vapour pressure of a species in solution will depend on availability of relevant information (composition {mol fractions and activity coefficients} and the process temperature) on all components of the mixture. It is clear that all such information will not always be available. Approximated values for these parameters have thus been proposed to allow estimation of vapour pressure and intrinsic emission factors in these situations.

3.2.7 Handling liquid resulting in mist

Handling of low-volatile liquids (e.g. vapour pressure ≤ 10 Pascal) will predominately lead to exposure due to aerosol formation. Because the possibility of aerosol formation is mainly determined by the activity (activity emission potential) that is performed (as described in Chapter 3.3), intrinsic properties of liquids that determine the likelihood of aerosol release are not documented in the scientific literature. The main intrinsic property that might influence the potential for aerosol formation is probably viscosity of the product. It is anticipated that handling of liquids with low viscosity (like water) results in more aerosol production as compared to handling of liquids with high viscosity (like oil) as indicated in the Table below..

Table 3.2.14 Propensity of a low-volatile liquid to produce aerosols as a result of handling the product.

Category	**Assigned value**
Liquids with low viscosity (like water)	1.0
Liquids with medium viscosity (like oil)	0.3

Highly viscous products like resin or paste appear to have stronger binding forces and therefore do not lead to the formation of aerosols during the handling of these products. We assume that if highly viscous products do not contain volatile substances, there is no potential for aerosol exposure through inhalation.

The molar fraction of the chemical substance in the product is linearly related to the emission of the chemical (i.e. a 10% content of the chemical substance in the product gives a 10 times lower emission than a pure substance).

This category also includes powders dissolved in a liquid matrix (e.g. copper in anti-fouling paint, biocides dissolved in water).

3.2.8 Handling molten or heated metal resulting in fumes

Composition of metal alloys and the temperature of the metal are considered as underlying determinants for substance emission potential. The exposure weighting for composition is based on the percentage by mass of that component in the mixture (Table 3.2.15).

Table 3.2.15 Compositional determinant effect on exposure weighting

	% composition	weighting
Very small	<1 %	0.005
Small	1 – 5 %	0.03
Minor	5 – 20 %	0.075
Substantial	20 – 50 %	0.3
Main	50 – 90 %	0.7
pure metal	> 90 %	1

The exposure weighting for the temperature is expressed by Equation 10. This shows that the value of the exposure weighting for a component of the molten metal mixture is considered to be high when the temperature of the mixture is greater than the melting point of the metal of interest in the metal mixture (Table 3.2.16). This is irrespective of the vapour pressure of that component at that temperature and so may be more significant for volatile components.

$$\frac{T_{mixture}}{MPt\ of\ metal\ A} \qquad \text{Equation 10}$$

where

$T_{mixture}$ = temperature of the molten metal mixture in ^{o}C

MPt metal A = melting point temperature of the component of interest, metal A, in °C

The weightings that result from equation 10 used to calculate the substance emission potential are described in the Table below.

Table 3.2.16 Temperature determinant effect on exposure weighting

Tmixture/MPt metal A	Examples	Weighting
> 2.5	$T_{mixture}$ = 1600 °C MPt metal A = 600 °C	3
1.5 - 2.5	$T_{mixture}$ = 1000 °C MPt metal A = 500 °C	2
< 1.5	$T_{mixture}$ = 625 °C MPt metal A = 500 °C	1

3.2.9 Handling liquid resulting in fumes

This type of emission is outside the applicability domain of the current ART version.

3.2.10 Handling gas

This type of emission is outside the applicability domain of the current ART version.

3.2.11 References

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3.3 Activity emission potential

3.3.1 Introduction

Activity emission potential describes the potential of the activity to generate exposure and is determined by the following characteristics: type and amount of energy transfer, scale, and product-to-air-interface. An “activity” is here defined as a specific delimited process step with handling characteristics that differentiate it from other process steps. Activities with similar underlying determinants are grouped in the same Activity Class. Activity emission potential categories are defined for each Activity Class.

The specific range of scores may differ for each Activity Class. Hence, each Activity Class may cover a different part of the total range of exposure weights of the principal MF “activity emission potential”. We use a predefined list of exposure weights on a logarithmic scale to determine the activity emission potential. The exposure weights for activity emission potential range from 0.001 to 100. This is similar to the approach that was used in Stoffenmanager (Marquart et al., 2008), although the range in exposure weights is much broader in the present approach. This five orders of magnitude range in weights in conjunction with the weights for the other principal Modifying Factors provides a good reflection of the total range in exposure levels across different substances, industries and scenarios.

3.3.2 Use of published exposure studies

To generate activity emission potential scores for each Activity Class we compared exposure measurements from different measurement series described in published literature and our own archives. Measured exposure data were not available for all activity classes and for each category in the activity classes. In these cases we assigned scores by interpolation based on the available evidence in other activity classes and by using judgments from members of the ART consortium and a variety of independent experts in Europe.

For this process exposure surveys representing unambiguous scenarios with well described contextual information were selected as indicator studies. These indicator studies were used to calibrate the valuation procedure. Indicator studies reflect only a very small proportion of the total available evidence and thus other published exposure studies were also used as supplementary information in the expert judgements.

The indicator studies reflect different situations with respect to all MF; e.g., activities with and without local controls, various room sizes etc. In order to enhance comparability between the studies, exposure levels were normalized to standard conditions reflecting a source in the near field, in a room of size 300 m^3, with 3 ACH, without local controls. Furthermore, exposure levels are normalized to represent a product with 100 percent active ingredient and for solid products adjustments are made towards a fine dust. To this end all non-default classifications of MF are selected and an overall adjustment factor is calculated. A normalized measure of central tendency is then obtained by multiplying exposure levels by this overall adjustment factor.

For example, exposure levels from operations in a very large room with 10 ACH (Multiplier=1) and LEV (Multiplier=0.1) are back transformed to a default exposure situation in a room size 300 m^3 with 3 ACH (Multiplier=1.6), without local controls (Multiplier=1). In this example the overall adjustment factor is 1.6 (for room size) multiplied by 10 (for local controls) and is thus equal to 16. The median exposure level would for this example study be multiplied by 16 to arrive at a normalized exposure level. Table 3.3.1 shows the selected indicator studies and related (normalized) exposure levels.

Table 3.3.1 Indicative aerosol exposure levels for selected categories in various Activity Classes.

No	Source	Product	Activity Class	Exposure situation	Measure of central tendency (mg/m^3)	
					Original	Adjusted
1	Conroy et al. (1995)	Solid objects	Abrasive blasting	Abrasive blasting (lead)	4.1-19.3	180-229
2	Conroy et al. (1995)			Abrasive blasting (chromium)	0.026-0.367	16.5-233
3	Semple et al. (2007)		Fracturing and abrasion	Open stone crushing	68.0	109
4	Chung et al. (2000)			Sawing of fibreboard	42.3	12.1
5	Chung et al. (2000)			Sanding of fibreboard	106.5	30.4
6	Marquart et al. (1999)	Powders	Falling of powders	Dumping of (big)bags	114.3	121.9
7	Dutkiewicz et al. (2001)		Movement and agitation of powders	Sieving of vessels in herb processing plant	15.1	65.9
8	Riala (1988)			Dry sweeping after demolition	32	32
9	Riala (1988)			Vacuum cleaning of contaminated floor	3.4	3.4
10	Lillienberg et al. (2008)	Liquids	High speed processes	Small-scale applications of various MWF	0.13	1.9
11	Simpson et al. (2003)			Small-scale applications of various MWF (water-mix)	0.13	0.95
12	Simpson et al. (2003)			Small-scale applications of various MWF (mineral oil)	0.67	4.9
13	Hands et al. (1996)			Small-scale applications of various MWF (enclosure)	0.21	3.0
14	Hands et al. (1996)			Small-scale applications of various MWF (enclosure)	0.45	6.5
15	Hands et al. (1996)			Small-scale applications of various MWF (no enclosure)	0.48	0.77
16	Links et al. (2007)		Spray applications	Air less spraying of antifouling paint	2.1	3.1
17	Van der Jagt et al. (2004)			Spraying biocides for pest control	0.02	1.2
18	Links et al. (2007)		Spreading of liquid products	Rolling of antifouling paint	0.01	0.17
19	Garrod et al. (2000)			Rolling of antifouling paint	0.04	0.06
20	Garrod et al. (2000)			Rolling of preservative	1.63	2.6
21	Kiilunen et al. (1997)		Activities with bath	Nickel electroplating	0.006-0.08	0.1-1.3

In the next paragraphs the activity emission potential and the assignment of exposure weights is described per activity (sub)class, which are summarized in Table 2.4.2. Normalized exposure levels in the above table as well as supplementary information from various other studies are used to underpin the expert judgements. Results are discussed separately for Activity Classes related to handling of solid objects, powders, granules or pelletized material, and liquids (vapour and mist).

3.3.3 Solid objects

This category includes wood, stone and metal for the current version of ART and may be expanded with other types of solid objects like plastics, glass, etc. In this category ‘fracturing and abrasion’ and ‘abrasive blasting’ are described in separate Activity Classes.

3.3.3.1 Activity Class: Fracturing and abrasion of solid objects

This Activity Class describes exposure as a result of fracturing of solid objects due to crushing or demolition activities or exposure arising from the application of abrasive wheels and polishers. In the case of rotating tools, the air movements created may be substantial and source air may be channelled and directed by the rotating tool as a jet back towards the operator (Hamill et al., 1991). Hence, an important factor affecting dust exposure is the operator’s posture during the activity, which is however difficult to quantitatively assess and has therefore not been taken into account in deriving the exposure weights.

The technique is probably a good proxy parameter that describes a number of (combined) determinants for exposure intensity, including energy input, transmission of forces from tool to surface, and surface area treated or crunched per unit of time. Also the particle size emitted depends on the applied technique and force. Chopping with an axe emits mostly large chunks. Manual sawing emits large particles, while due to its many contact moments with the surface, a circular saw, emits a larger percentage of small particles. Similarly, the roughness of the sanding paper used influences the particle sizes emitted with finer grades producing much finer dust which remains airborne for longer (Chung et al., 2000).

All of the above parameters cannot be separately used in a generic model. Therefore, a general categorization of “technique class” is proposed that differentiates between activities such as manual sawing, manual sanding, circular saw, chain saw, sanding machines, manual demolishing, jack hammering, demolition using power tools, mechanical crushing, etc. The “technique class” thereby combines a large number of the underlying exposure determinants which are often inter-related and therefore not easily distinguishable.

The material treated is another important determinant of exposure. Not all techniques will be relevant for each material. For example, it is not normal practice to use a hand saw on glass, a chain saw on rubber or a jack hammer on plastics. In addition, the absolute levels of exposure will be different for a given technique (e.g., polishing) applied to different materials (e.g. wood vs. stone). The need for a separate calibration for different types of material will be explored (i.e., wood, stone, metal, plastic, other). A separate table with classes and exposure weights will be given for wood and stone.

Wood

In the assignment of exposure weights for wood we assume a maximum weight of 30. This is in accordance with task-based exposure figures found in the construction industry by Spee et al. (2007) with maximum values for inhalable dust of approximately 30 mg/m^3. High energy activities like using a circular saw or mechanical sanding are reported to have exposure levels around 10 - 30 mg/m^3 (Spee et al., 2007; Hursthouse et al., 2004). Other activities like milling and drilling holes appeared to produce lower exposure levels of around 3 - 10 mg/m^3 (Scheeper et al., 1995). Activities with very low exposures are not reported in isolation.

Results from some studies suggest that exposure levels are higher for sanding operations as compared to sawing (Chung et al., 2000). The indicator study of Chung et al. (2000) in a ventilated confined space showed exposure levels of approximately 40 and 100 mg/m^3 for sawing and sanding, respectively. Normalizing these figures to a situation in a ventilated room of approximately 300 m^3 would result in exposure levels of 12 and 30 mg/m^3, respectively. Reames et al (2001) measured lead inhalation exposure levels during lead abatement operations in the San Francisco Bay area indoors and outdoors. Geometric mean exposure during interior manual wet sanding was 0.001 mg/m3. During paint scraping a hand-held garden spray bottle was used to apply water on the surface treated. The geometric mean exposure during interior manual scraping was 0.0077 mg/m^3. Exterior manual scraping resulted in a geometric mean exposure of 0.0051. The geometric mean paint lead content was 2.3 % (European Chemicals Bureau, Lead Risk Assessment report). Normalizing the median exposure level for interior sanding, interior wet scraping and exterior wet scraping to a situation in a standard ventilated room without wetting would result in exposure levels of 0.3 mg/m^3, 2.6 mg/m^3 and 1.7 mg/m^3, respectively.

Table 3.3.2 Classes and related exposure weights representing emission potential for fracturing and abrasion of wood objects.

Description	**Examples**	**Exposure weights**
Mechanical sanding of wood resulting in large amount of dust	belt sanding, handheld sanding machine	30
Mechanical handling of wood resulting in large amounts of dust (e.g., large speed of moving work pieces or rotating cutting blades) – excluding sanding	milling operations, lathe, circular saw	10
Mechanical handling of wood resulting in limited amount of dust	planer, chainsaw, shredder, drilling of holes	3
Manual handling of wood resulting in limited amount of dust	manual sawing or sanding, scraping of paint	3
Manual handling of wood resulting in very limited amount of dust	screw setting, manual planing	0.3

Table 3.3.3 Classes and related exposure weights representing process containment during fracturing and abrasion of wood objects.

Classification	**Examples**	**Exposure weights**
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls.	Enclosed cover on a circular saw (relatively small openings are possible)	0.3

Stone

The exposure levels for operations with stone are considered to be higher than those with wood. A maximum exposure weight of 100 is assumed. The assignment of exposure weights is to a large extent based on respirable exposure values as inhalable exposure levels were scarce in the literature.

For task-based measurements high exposure levels were found. This was especially the case for high energy abrasive activities of large surfaces like grinding concrete floors and sawing and cutting of concrete blocks. Geometric mean respirable dust exposure for surface grinding was up to 165 mg/m^3 in the absence of control measures. Block cutting with masonry saw showed a geometric mean respirable dust level of 90 mg/m^3 where controls were not installed (Flynn and Susi, 2003). Application of the cut-off saw without controls produced respirable exposure levels between 8 – 58 mg/m^3 outdoors and 184 mg/m^3 during laboratory conditions indoors, respectively (Thorpe et al., 1999). Tjoe Nij et al. (2003) found a respirable exposure level of 37 mg/m^3 for sawing in lime sandstone using a MiniRam measurement.

High exposure levels will also occur during activities like operating open stone crushing machines or demolition activities using power tools. Semple et al. (2009) measured mean respirable exposure levels of 18.9 mg/m^3 in an Indian stone crushing site. Somewhat higher levels were found by Sivacoumar et al. (2001, 2006) (i.e., 34.1 and 35.7 mg/m^3, respectively). Lower respirable exposure levels were reported in stone crushing operations (mean dust levels of 0.8-7.8 mg/m^3) by Fulekar (1999). Mean exposure levels from stationary measurement points in 9 crushed rock plants in Finland were approximately 30 and 10 mg/m^3 for total and respirable dust, respectively (Junttila et al., 1997). It should be noted that the actual source (crushing machine) is probably often in the far field of the worker during a part of the shift. The indicator study of Semple et al. (2009) showed inhalable dust levels of 68 mg/m^3 for stone crushing, resulting in normalised levels of 109 mg/m^3.

Smaller scale abrasion using hand held tools results in somewhat lower exposure levels. A mean respirable particulate exposure of 24 mg/m^3 was observed during concrete finishing while workers used hand-held grinders without LEV (Akbar-Khanzadeh and Brillhart, 2002). Comparable results were obtained for the removal of mortar using a hand-held grinder (Flynn and Susi, 2003). Croteau et al. (2004) found geometric mean respirable dust levels during hand-held grinding between 0.78 and 12.7 mg/m^3 (GM=4.53 mg/m^3) for different, large-scale and open construction sites.

An exposure survey in Dutch construction industry showed geometric mean respirable exposure levels of around 10 mg/m^3 for demolition workers using power tools like jack hammers. For making recesses using millers, exposure levels around 3 mg/m^3 are described; some of these recess millers used LEV (Lumens and Spee 2001). Tjoe Nij et al. (2003) found a respirable dust level of 14 mg/m^3 for recess milling in lime sandstone using a MiniRam measurement. Activities with lower exposure levels are not reported in isolation.

Based on the collated evidence we propose exposure weights according to the following logarithmic scaling: 0.3 - 100.

Table 3.3.4 Classes and related exposure weights representing emission potential for fracturing and abrasion of stone objects.

Description	Examples	Exposure weights
Mechanical pulverization of large amounts of stone or large objects	Stone crushing machines, demolition using explosives, using a jack hammer to demolish large surfaces, demolition using a crane	100
Mechanical treatment / abrasion of large surfaces	Surface grinding, smoothing of concrete walls and floors, cutting concrete blocks using masonry saw	100
Mechanical treatment / abrasion of small-sized surfaces	Using hand-held grinders to remove mortar	30
Mechanical pulverization of stones	Using power tools like jack hammers to demolish small surfaces, recess millers	10

Manual pulverization or treatment / abrasion of small sized objects	Use of non-powered tools like hammer or chisel, manual polishing	3
Careful breaking stones	Mechanical tile breaking	0.3

Table 3.3.5 Classes and related exposure weights representing process containment during fracturing and abrasion of stone objects.

Classification	Examples	Exposure weights
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls.	Enclosed stone crushing machine (relatively small openings are possible)	0.3

Metals

During production of inorganic pigments milling calcinated material in a closed system results in a median stationary inhalation exposure to antimony of 0.003 mg/m3 (max 0.007 mg/m3, 90% 0.005 mg/m3, n=22, static measurements). Note, whereas exposures measured after the calcination stage may relate to antimony, they do not represent diantimony trioxide in view of the chemical conversion to spinel type pigments from which antimony or other metals have been shown to be non-bioavailable. As the milling and associated transport are in an entirely closed system, exposure will possibly be caused during the filling of bags which is included in this scenario (European Chemicals Bureau, Antimony Risk Assessment Report).

Used lead-acid batteries are used for secondary lead production. During the secondary lead production of batteries the batteries are shreddered to reduce the batteries to small pieces which are cleaned afterwards. The water used for the washing process contains sulphuric acid and lead oxide paste and is subsequently subjected to a neutralisation and desulphurisation process. The shredder process is automated (no handling) and LEV is present. The lead content of a typical lead-acid battery is 60 percent. During the shredder and washing process a personal median inhalation lead exposure level of 0.038 mg/m3 is measured (maximum 6.306 mg/m^3, 90% 0.266 mg/m^3, n=208; European Chemicals Bureau, Lead Risk Assessment Report). Normalizing the median exposure level to a situation in a ventilated room would result in an exposure level of 0.38 mg/m^3.

Sheets rolls of lead are usually further divided into smaller portions in size by sawing or slitting operations. Dividing rolls of lead will generate fine lead particles through abrasion, which in turn are collected for recycling. During the process LEV is present and there is no direct handling. Median lead exposure levels of 0.062 mg/m^3 (maximum 2.090 mg/m^3, 90% 1.902 mg/m^3, n=10; European Chemicals Bureau, Lead Risk Assessment Report). Normalizing the median exposure level to a situation in a ventilated room would result in an exposure level of 1.0 mg/m^3.

A process in the production of lead metal sheets is the rolling action to decrease the castings or slabs to sheets with a thickness sometimes at or below 2 mm. Per shift approximately 50-60 tons of lead are processed. The highly automated process is performed in an enclosed space with ventilation available. A median exposure level of 0.053 mg/m^3 was found (European Chemicals Bureau, Lead Risk Assessment Report). Normalising the exposure situation gives an exposure of 0.18 mg/m^3.

During sanding of cars using non-ventilated orbital sanders total dust concentration ranging from 2.4 to 86 mg/m^3 were found (sampling time ranged from 9 to 43 minutes). Sanding was performed in a non-ventilated room. Lead and chromium concentration ranging from < 0.0009 to 0.013 mg/m^3 and < 2.0 to 90.4 µg/m^3 where found, respectively (Cooper et al., 1993).

Aluminium oxide abrasives are used in the from of grinding disks, wheels and coated abrasive belts for surface grinding of process containers of stainless steel. During grinding of stainless steel total dust concentrations in the breathing zone varied between 1 and 11 mg/m^3 (n=9). The variation of dust concentration in hard metal grinding using an aluminium oxide wheel was 5 to 9 mg/m^3. In surface grinding the dust composition indicates that 50% of the particles originate from the work piece, the rest of the dust comes from aluminium oxide abrasives and polishing materials (Koponen et al. (1981)).

Zaghbani et al (2009) studied the generation of microparticles and nanoparticles during dry and wet milling processes at high cutting speeds ranging from 300 to 900 m/min. They found that particle mass concentration increases with increased cutting feed but decreases with the cutting speeds. The authors found that the higher the material temperature, the lower the generated dust. For particles 0.5 – 1 µm wet machining resulted in a higher mass concentration than dry machining. For particle sizes between 1 and 10 µm the mass concentration of particles generated in wet milling is much lower than the particle mass concentration in dry milling. Regarding nanoparticles they found that speed and the feed do not significantly influence the generation of nanoparticles during wet milling, however, for dry milling, an increase in cutting speeds helped to reduce the nanoparticle mass concentration.

Table 3.3.6 Classes and related exposure weights representing emission potential for fracturing and abrasion of metal objects.

Description	**Examples**	**Exposure weights**
Mechanical abrasion or fracturing of metal resulting in small amount of dust	Sanding metal objects. grinding steel	3
Mechanical abrasion or fracturing of metal resulting in very limited amount of dust	Shredding of batteries, sawing or slitting of metal objects	1
Mechanical deforming of metal	Rolling metal sheets	0.1

Table 3.3.7 Classes and related exposure weights representing process containment during fracturing and abrasion of metal objects.

Classification	**Examples**	**Exposure weights**
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls.	Enclosed cover on a battery shredding process (relatively small openings are possible)	0.3

3.3.3.2 Activity Class: Abrasive blasting

Abrasive blasting is a common method for removing surface coatings or contamination. Compressed air is used to propel abrasive material towards the surface at high velocity. The air contaminants that are released include the base material being blasted, the surface coatings being removed, and the abrasive being used (e.g. coal slag, copper slag, steel grit, silica sand). The exposure level depends on the surface being blasted (i.e. thickness of coating, concentration of contaminant in coating), the abrasive media used, and the blasting technique.

In addition to dry blasting various alternative techniques exist such as ultrahigh-pressure (UHP) water jetting and wet abrasive blasting (Flynn and Susi, 2004). Also various automated abrasive blasting equipment as well as vacuum blasting systems exist or are under development (Echt et al., 2000). Currently there is little or no exposure data available on abrasive blasting to inform decisions on the relative values assigned to the different techniques. Changing the abrasive medium will obviously alter exposure to the abrasive material, but exposure to surface coating components may be unaffected. Currently, ART will only consider exposure arising from surface coatings during abrasive blasting.

Conroy et al. (1995) investigated lead and chromium exposure levels during abrasive blasting by bridge painters in two seasons. Mean lead exposure during blasting a bridge (3% lead in paint) and viaducts (0.81 % lead in paint) were 5-19 mg/m^3 and 4-9 mg/m^3, respectively. Mean chromium exposure during blasting in one season was between 0.026-0.367 mg/m^3 (0.066 and 0.046 % chromium in paint, respectively). All sites where blasting occurred were enclosed with plastic tarpaulins, and each crew consisted of several blasters. Normalized values ranged from 16.5 - 233 mg/m^3.

Similar lead figures were found by Vivji et al. (2009) using task-based measurements to assess exposure during abrasive blasting (mean inhalation lead exposure: 23 mg/m^3), although the lead content in the paint was not given. The bridge surface preparations were conducted inside contained structures designed to minimize lead emission to the environment. Similarly, Jacobs (1998) describes mean lead exposure levels ranging from approximately 0.5 to 15 mg/m^3 for different paint removal activities by abrasive blasting. Yet, lead contents in the removed paint were not given. Eight-hour TWA lead concentrations were orders of magnitude lower (i.e., 0.003 – 0.2 mg/m^3) among abrasive blasting workers at four US air force facilities (Aizenberg et al., 2000). This discrepancy is probably due to the fact that monitored workers were typically engaged in abrasive blasting for short periods of time during the total sampling period.

Links et al. (2007) found mean copper exposure levels of 0.82 mg/m^3 during removal of antifouling paints from boats. The copper content of the prior coating was not given. The abrasive blasting was conducted in a large boatyard without any containment.

Hence, there is a large range in exposure values for dry abrasive blasting. Exposure data for alternative techniques are missing. Based on the available exposure data we propose the following range in exposure weights for abrasive blasting techniques.

Table 3.3.8 Exposure weight for activity emission potential of Activity Class 'abrasive blasting'

Description	**Example**	**Exposure weight**
Abrasive blasting of very large surfaces	Removing (anti-fouling) paint from ships or bridges. Abrasive blasting is powered by compressed air.	100
Abrasive blasting of large surfaces	Blasting of e.g. car bodies, trailer frames	30
Abrasive blasting of small parts	Blast cleaning of small statues, bicycle frame parts	10
Micro-abrasive blasting	Small-scale abrasive blasting process in e.g. medical aids (blasting area of about a few cm).	1

Table 3.3.9 Exposure weights for the type of abrasive blasting technique.

Description	**Example**	**Exposure weight**
Dry abrasive blasting	Abrasive blasting is powered by compressed air.	1
Wet abrasive blasting	Includes systems where a mixture of abrasive and water is propelled by	0.3

	compressed air, where water is added to abrasive blasting nozzle, or water jet stripping systems.

Table 3.3.10 Exposure weights for direction of blasting

Description	**Exposure weights**
Abrasive blasting in any direction (including upwards)	3
Only horizontal and downward blasting	1
Only downward blasting	0.3

3.3.4 Powders, granules or pelletized material

For this product type the following Activity Classes are distinguished: impaction on contaminated solid objects, handling of contaminated solid objects or paste, spray application of powders, movement and agitation of powders, granules or pelletized material, transfer of powders, granules or pelletized material, compressing of powders, granules or pelletized material, and fracturing of powders, granules or pelletized material.

3.3.4.1 Activity Class: Impaction on contaminated solid objects

In this activity class, impaction of a tool on a (contaminated) surface results in disturbances of particles that may subsequently become airborne from this surface. Examples are hammering, nailing, piling and mounting. The most important determinants of exposure are the level of contamination of the surface and the amount of energy applied to the surface during impaction. The exposure mechanism and assigned exposure weights are closely linked with Activity Class ‘handling contaminated objects’.

Although the above mentioned tasks are not regularly measured separately, some measurement data was retrieved. These data require careful interpretation as inferences have to be drawn from shift measurements sometimes covering an amalgam of different activities. In addition, information about possible presence of control measures, level of contamination of the products and exact force applied (for instance automated or manual nailing) was not available.

In a study in the Danish furniture industry, in which inhalable dust was measured with passive samplers, the geometric mean inhalable dust concentration was 0.71 mg/m^3 and 0.55 mg/m^3 for handling and assembling and 0.79 mg/m^3 and 0.36 mg/m^3 for store men in 1997-1998 and 2003-2004, respectively (Schlunssen, et al., 2008). An analysis of airborne wood dust concentrations in US industries over the years 1979-1997 showed a geometric mean wood dust concentration of 0.86 mg/m^3 (range <0.02-13.1) for assemblers in the furniture industry (Teschke, et al., 1999). An Australian survey in selected wood industries (sampling period of 3-8 hr.) found personal geometric mean inhalation exposure levels for wood dust of 1.26 mg/m^3 (range 0.21-9.4, n=17) for assembling, 1.03 mg/m^3 (range 0.8-1.7, n=3) for nailing and 2.01 mg/m^3 (range 0.46-7.1, n=5) for stacking (Australian Safety and Compensation Council, 2008). Exposure levels during impaction under well controlled conditions (e.g. pharmaceutical industry) are not reported.

Exposure levels described are approximately in line with findings described for handling contaminated objects (next paragraph). Exposure weights are a multiplication of weights for level of contamination and type of handling.

Table 3.3.11 Classes and related exposure weights for level of contamination

Description	Examples	Exposure weights
Impaction on substantially and visibly contaminated objects (layers of more than 0.5 kg).	Impaction on heavily contaminated filters	3
Impaction on objects with visible contamination (object covered with fugitive dust from surrounding dusty activities)	Hammering on contaminated objects	1
Impaction on objects with limited residual dust (thin layer visible)	Impaction on limited contaminated drums or transfer line.	0.3
Impaction on slightly contaminated objects (layers of less than few grams)	Impaction on objects after closed filling operations.	0.1
Impaction on apparently clean objects	Impaction on drums coming out of a cleaning machine	0.001

The pressure, force or power in heavy mechanical impaction is easily 10 to 100 times as high as in normal impaction. However, it is unknown whether there is a similar effect on emission. Therefore a factor of 3 between heavy and normal impaction is suggested.

Table 3.3.12 Classes and related exposure weights for type of handling

Description	Examples	Exposure weights
Heavy mechanical impaction	Hydraulic hammers.	3
Normal impaction (manual or light mechanical)	Manual hammering, beating carpets	1

3.3.4.2 Activity Class: Handling of contaminated solid objects or paste

In this Activity Class movement of a contaminated solid object or handling pastes causes (re-) suspension of particles from this object into the air. Examples of activities in this activity class are sorting, stacking or carrying (e.g. stacking of bricks contaminated with cement dust can cause the release of cement particles into the air), disposal of empty (contaminated) bags, maintenance of contaminated equipment, or kneading of dough in bakeries. The relative change of movement of the object and the amount of contamination on the object determines the level of exposure.

Limited information is available for exposures during these activities. Most of these studies are conducted in plants with substantial surface contamination. Woskie et al.[1] found total dust exposures of 6.2 mg/m^3 for pelletizers in sodium borate workers. A Dutch study in bakery ingredient production found pelletizers stacking bags had average dust exposures of 2.5 mg/m^3 and storage workers in flour mills who did a lot of stacking of bags had exposures of 6.4 mg/m^3; packers in bakeries generally had exposures below 0.5 mg/m^3 (de Pater et al., 2003). A study of bag stackers in a mineral processing plant without control measures reported respirable dust exposure levels of around 0.5-1.5 mg/m^3 (Cecala et al., 2000). In an earlier study, respirable exposure levels for bag stackers were between 1.5-4 mg/m^3 (Cecala et al., 1989).

Used lead-acid batteries and secondary raw material including battery plant scrap, lead building scrap, cable sheeting and solder represent the main feed of typical secondary lead smelters. Used and returned batteries are transported to collection vessels using a semi-automated device and subsequently broken apart. During the handling of raw material and breaking apart LEV is present and no direct handling takes place. A median lead personal exposure level of 0.067 mg/m^3 (maximum 3.477 mg/m^3, 90 % 0.539 mg/m^3) was found (European Chemicals Bureau, Lead Risk Assessment Report). Normalizing the median exposure level to a situation in a ventilated room would result in an exposure level of 2 mg/m^3.

During internal logistics, which encompasses all inter-facility transport operations, quality control and engineering, within the scenario primary lead production a personal median exposure lead level of 0.050 mg/m^3 (maximum 2.020 mg/m^3, 90 % 0.192 mg/m^3) was found (European Chemicals Bureau, Lead Risk Assessment Report). Normalizing the median exposure level to a situation in a ventilated room would result in an exposure level of 0.1 mg/m^3. During internal logistics within the scenario secondary lead production a personal median exposure lead level of 0.079 mg/m^3 (maximum 2.02 mg/m^3, 90 % 0.318 mg/m^3) was found (European Chemicals Bureau, Lead Risk Assessment Report). Normalizing the median exposure level to a situation in a ventilated room would result in an exposure level of 0.1 mg/m^3.

A median exposure of 0.039 mg/m^3 (maximum 0.084 mg/m^3, 90% 0.079 mg/m^3) was found during packaging, storage, transport within the facility and shipment for the scenario lead sheet production (no contextual information available, European Chemicals Bureau, Lead Risk Assessment Report). Similar exposure levels were found during internal logistics, quality control and shipment within the scenario battery production (median 0.031 mg/m^3, maximum 0.323 mg/m^3, 90% 0.071 mg/m^3) (no contextual information available, European Chemicals Bureau, Lead Risk Assessment Report). Normalizing these median exposure levels to a situation in a ventilated room would result in an exposure level of 0.1 mg/m^3 approximately.

Exposure weights are a multiplication of weights for level of contamination and type of handling.

Table 3.3.13 Classes and related exposure weights for level of contamination.

Description	**Examples**	**Exposure weight**
Handling of substantially and visibly contaminated objects (layers of more than 0.5 kg).	Stacking cement bags with dust contamination (leakage from bag valve), disposal of empty contaminated bags, disposal of heavily contaminated filters, maintenance of heavily contaminated equipment	1
Handling of objects with visible contamination (object covered with fugitive dust from surrounding dusty activities)	Transport of contaminated objects, carrying contaminated bags, changing contaminated filters	0.3
Handling of objects with limited residual dust (thin layer visible)	Transportation of drums. Coupling/decoupling of transfer line Transport of contaminated metal objects, replacing filters	0.1
Handling of slightly contaminated objects (layers of less than few grams product)	Handling of slightly contaminated glass bottles or plastic kegs. Packaging of objects after closed filling operations.	0.03

Handling of apparently clean objects	Drums coming out of a cleaning machine	0.001

Table 3.3.14 Classes and related exposure weights for type of handling

Description	**Exposure weights**
Handling that departs from regular work procedures and involves large amounts of energy (e.g. rough handling or throwing of bags)	3
Normal handling, involves regular work procedures.	1
Careful handling, involves workers showing attention to potential danger, error or harm and carrying out the activity in a very exact and thorough (or cautious) manner.	0.3

3.3.4.3 Activity Class: Spray application of powders

In this paragraph the activity emission potential of the Activity Class ‘spray application of powders’ is described. This represents activities like dusting crops and powder coating. Processes like plasma spraying are described in another Activity Class.

For spraying of solids little quantitative data are available. Most exposure data are related to dusting of crops and powder coating. With regard to powder coating, fine particles are applied to an electrically earthed and electrostatic charged work piece via a pressurized electrostatic spray-application system. Because of trapping of the particles in the electrostatic field spraying is mostly done from one side; the surplus of powder can be recycled (Stear and Cooke, 1999). Spraying mostly takes place in spray booths, with the worker standing outside and spraying through an opening. However, in practice the workers also lean into the booths while spraying. In 1994 the HSE conducted an exposure survey, revealing a mean total inhalable dust concentration of 13 mg/m^3 (range 0.2-131 mg/m^3) during spraying coating powders, while 68% of the measurements during manual spraying and 60% of the measurements during automated spraying were above 3 mg/m^3. Poor working practices, such as leaning into the booth to spray the object, even when the spraying was automated (to touch up missed areas), generally resulted in high exposures (Stear and Cooke, 1999). Roff et al. (2004) reported inhalable dust concentrations of 2.8-3.6 mg/m^3 in a company spraying powders in a spray booth. However, the concentration during spraying alone was believed to be higher, since the measurement time also involved loading and cleaning the spray-gun and changing the work pieces.

A study involving dusting of crops with pesticides (10%w/w) with a knapsack blower reported a geometric mean inhalable dust concentration of 0.67 mg/m^3 including mixing and loading of the knapsack (Brouwer, et al., 1992). Llewellyn et al. found much lower exposure levels but these were based on a very limited number of measurements (Llewellyn, et al., 1996). This study did indicate that for dusting spraying in an upward direction results in significantly higher exposure than spraying downward or horizontal direction. Although data is too limited to quantify the difference it seems that a factor 3 difference like that observed for liquids is warranted.

Based on the considerations above exposure weights are proposed as described in the Table; exposure weights are a multiplicative combination of technique and spray direction.

Table 3.3.15 Classes and related exposure weights for activity emission potential of Activity Class ‘spray application of powders.

Description	Example	Exposure weights
Powder coating	Powder spraying using electrostatic spray gun	10
Dusting using blower	Dusting crops with knapsack dust blower	3

Table 3.3.16 Exposure weight for spray direction

Description	Exposure weights
Spraying in any direction (including upwards)	3
Only horizontal and downward spraying	1
Only downward spraying	0.3

3.3.4.4 Activity Class: Movement and agitation of powders, granules or pelletized material

In this activity class, movement and agitation results in disturbance of powders causing dust particles to become airborne. Examples are sweeping or brushing of a surface with material on it, use of pressured air, sieving or shaking of (empty) bags, shaking of a silo hose, and automated or manual mixing of materials. Most important determinants are the amount of substance and the amount of energy applied to it. The Activity Class is distinct from ‘handling contaminated objects’ in that the applied level of energy and thus agitation of dust is generally higher.

A large amount of literature is available on exposure levels during sweeping and related cleaning activities. In a Dutch study on flour processing sectors task specific real time measurements during sweeping showed on average inhalation exposure levels of 10 to 12 mg/m^3 for cleaners whom carried out a substantial amount of sweeping: short-term peak exposure levels of 20 to 50 mg/m^3 were generally found and using pressured air resulted in peak exposure in excess of 100 mg/m^3 (de Pater, et al., 2003; Meijster, et al., 2008). A study of cleaners and wood dust exposure found shift-based exposure levels of around 10 mg/m^3 (Black, et al., 2007). In a study in the construction industry respirable dust exposure levels of around 30 mg/m^3 were found for dry sweeping activities, while wet sweeping resulted in exposure levels around 5 mg/m^3 (Spee, et al., 1998). In an indicator study among Finnish construction site cleaners, Riala (1988) found inhalable exposure levels of around 32 mg/m^3 for dry sweeping and 3 mg/m^3 for vacuum cleaning.

Exposure information is also available for other activities in this Activity Class. For shaking of big bags short-term peak exposures of up to 50 mg/m^3 were identified when using real time measurements: beating on the bag with a tool resulted in increased exposure levels up to 70 mg/m^3. Shaking of a silo hose gave exposures up to 20 mg/m^3 (de Pater, et al., 2003). Sieving in food and herb processing plants resulted in geometric mean exposure levels of approximately 20 and 15 mg/m^3, respectively (Lacey et al., 2006, Dutkiewicz et al., 2001). Normalization results in levels of approximately 66 mg/m^3. A median exposure level of 229 mg/m^3 was measured during sieving very large quantities of peat moss. However, only stationary exposure measurements were available in this study (Meriaux et al., 2006). Mixing of diantimony trioxide results in a mean personal exposure to antimony of 3.2 mg/m^3 (no contextual information available; European Chemicals Bureau, Diantimony Risk Assessment Report; no indication about amount handled given in RAR).

Exposure weights are a multiplicative combination of amount agitated, type of agitation, and level of process enclosure.

Table 3.3.17 Classes and related exposure weights for quantity of agitated product

Description	**Example activities**	**Exposure weights**
Movement and agitation of 1000 kg or more	Sieving big bag volumes in large production plants (e.g. sieving peat moss)	30
Movement and agitation of 100 - 1000 kg	Cleaning large heaps of dust or debris (after demolition) Sieving, mixing or blending in vessels	10
Movement and agitation of 10 - 100 kg	Cleaning heavily contaminated floors (e.g. after dusty activities like bagging or abrasion) Sieving, mixing or blending in large buckets	3
Movement and agitation of 1 - 10 kg	Cleaning floors (sweeping) covered with fugitive dust Manual sieving, mixing or blending	1
Movement and agitation of 0.1 - 1 kg	Using brush and dustpan to clean up small spills Manual sieving, mixing or blending	0.3
Movement and agitation of 10 - 100 gram	Using brush and dustpan to clean up small spills Manual sieving, mixing or blending	0.1
Movement and agitation of < 10 gram	Cleaning valves/machinery/equipment with wipe, mixing on laboratory scale	0.03

Table 3.3.18 Classes and related exposure weights for type of handling

Description	**Examples**	**Exposure weights**
Application of compressed air	Using compressed air to clean e.g. machines	30
Other handling with high level of agitation	Sweeping of floors, sieving, mechanical mixing	3
Handling with low level of agitation	Manual mixing	1

Table 3.3.19 Classes and related exposure weights representing process containment during falling of powders, granules or pelletized material.

Classification	**Examples**	**Exposure weights**
Open process		1.0
Handling that reduces contact between product and adjacent air.	Contained sieving of big bags with only small opening	0.3

Note: This does not include processes that are fully contained by localized controls (see next questions).

3.3.4.5 Activity Class: Transfer of powders, granules or pelletized material

This paragraph describes the emission potential of activities like bagging powders/granules, dumping powders/granules in mixers, and loading barges with minerals or cereals. Two subclasses are defined: falling powders and vacuum transfer. The emission during the subclass 'falling powder' is mainly driven by falling height and use rate. The emission during vacuum transfer is mainly driven by use rate. Obviously, personal differences in handling are also important, yet very difficult to quantify. The importance of the first two parameters was convincingly shown in experimental studies. The measured aerosol concentrations indicated an increase with mass and drop height. However, the increase in aerosol concentration was less than proportional to the increase in mass, probably because most of the aerosols are generated from the front of the product stream. Particles in the middle of the stream interact much less with interacting with adjacent air (Plinke et al. 1991; Heitbrink et al., 1992; Ansart et al., 2009).

Therefore in the assignment of exposure weights we assume a disproportional increase of emission with a factor of 3 with each order of magnitude increase in mass. Furthermore, drop height is arbitrarily dichotomized into two categories (< 0.5 m; ≥ 0.5 m) with a factor 3 increase in emission potential for high dropping heights. In addition, careful handling of products is of major influence. Aerosol generation can be reduced by careful handling and minimizing contact between falling powder and air (Heitbrink et al., 1992). To take this into account, a simplified distinction is made between 'careful handling' and 'normal' handling. Additional subtle differences in personal behaviour were considered to be too difficult to take into account in this generic model. Careful handling is assumed to result in a reduction of exposure by a factor of 3.

As a benchmark for the total range in exposure weights measurements from the calibration dataset were used. On one end of the spectrum measurements during transhipment (without local control) were used, reflecting exposure levels up to 50-200 mg/m^3. These results are corroborated by studies that estimated exposure levels up to 100 mg/m^3 for bag dumping and filling operations without engineering controls (Heitbrink and McKinnery 1986; Cooper et al. 1983; Marquart et al., 1999). The low end of the distribution is reflected by handling small amounts in pharmacy shops (without local control) with inhalable dust concentrations around 0.01-0.05 mg/m^3. The exposure weights for falling powders are broken down into 4 multiplicative factors: quantity transferred, drop height, type of handling, and process enclosure. For vacuum transfer two multiplicative factors are taken into account: quantity transferred and process enclosure. Exposure levels for vacuum transfer are considered lower as compared to falling powders.

3.3.4.5.1 Activity subclass: Falling powders

Table 3.3.20 Classes and related exposure weights for quantity transferred.

Description	Examples	Exposure weights
Transferring more than 1000 kg/minute	Large scale transfer with big bags	30
Transferring 100 – 1000 kg/minute	Automated dumping of powders (e.g. auger or conveyor belt)	10
Transferring 10 – 100 kg/minute	Manual dumping of powders	3
Transferring 1 – 10 kg/minute	Scooping activities	1

Transferring 0.1 – 1 kg/minute	Filling bottles	0.3
Transferring 10 – 100 gram/minute	Small-scale scooping for sampling	0.1
Transferring less than 10 gram/minute	Very small scale weighing (fine adjustments) and scooping in laboratory	0.03

Table 3.3.21 Exposure weights for type of handling

Description	**Exposure weights**
Routine transfer	1
Careful transfer involves workers showing attention to potential danger, error or harm and carrying out the activity in a very exact and thorough (or cautious) manner. e.g. careful weighing in laboratory	0.3

Table 3.3.22 Exposure weights for drop height

Description	**Exposure weights**
Drop height > 0.5 m	3
Drop height < 0.5 m	1

Table 3.3.23 Classes and related exposure weights representing process containment during falling of powders, granules or pelletized material.

Classification	**Examples**	**Exposure weights**
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Dumping powders in a big bag through a small dumping opening	0.3

3.3.4.5.2 *Activity subclass: Vacuum transfer*

Table 3.3.24 Classes and related exposure weights for activity emission potential of sub Activity Class 'Vacuum transfer of powders'.

Description	**Examples**	**Exposure weights**
Transferring more than 1000 kg/minute	Large scale vacuum transfer from large vessels	3

Transferring 100 – 1000 kg/minute		1
Transferring 10 – 100 kg/minute		0.3
Transferring 1 – 10 kg/minute		0.1
Transferring 0.1 – 1 kg/minute		0.03
Transferring 10 – 100 gram/minute		0.01
Transferring less than 10 gram/minute	Micro powder transfer systems	0.003

Table 3.3.25 Classes and related exposure weights representing process containment during vacuum transfer of powders, granules or pelletized material

Classification	**Examples**	**Exposure weights**
Open process	Vacuum transfer from open reservoir to enclosed reservoir	1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls.	Vacuum transfer from reservoir with small opening to enclosed reservoir	0.3

3.3.4.6 Activity Class: Compressing of powders, granules or pelletized material

This activity class describes exposure as a result of the compression of solid products due to crushing and impaction. Examples are compaction of soil, production of tablets in the pharmaceutical industry, granulation, or pelletization of products (e.g., wood, pellets).

The compression of the products is a combination of crushing and impaction, resulting in a more condensed product in a certain shape, with the possible displacement of air or water from the product that is being compressed.

The relevant determinants for this activity class are the force applied to the product and the size and/or surface of the product that is compressed. In general, the force of impaction is applied in a controlled manner to be able to result in certain product (tablet, pellet).

Not much information is available about exposure levels for the tasks in this activity class, however, to understand possible exposure levels. Some indicative exposure levels are presented. Stationary wood dust measurements during the industrial production of wood pellets (placed at positions where high wood dust exposure was expected) resulted in geometric mean concentrations of 0.32 mg/m^3 (range <0.10-2.2) at the pellet press and measured a concentration of 0.49 mg/m^3 at a briquette machine (which is a more mechanical process with higher impact on the wood) (Edman, et al., 2003). In a follow up study in the wood pellet production industry mean personal exposure levels of 2.9 and 0.42 mg/m^3 were found for workers operating the pellet press and briquette machine, respectively (Hagström et al., 2008). The machines were probably to a large extent in the workers' far field. Similar exposure levels (GM=2.59 mg/ m^3) for pressing were found in Australia (Australian Safety and Compensation Council, 2008). In a pharmaceutical plant, a mean personal total airborne particulate matter concentrations of 6.5 µg/m^3 (range 1.6-13) was measured during drug compounding/tablet preparation of methotrexate (Sessink, et al., 1994). Real-time measurements with a DataRam revealed mean respirable dust concentrations during dry conditions of 11.1 mg/m^3 (range 5.9-17.1) and 7.8 mg/m^3 (range 6.4-9.0) for compacting soil (ca.

270 m² in 30 minutes) with a light (with regard to weight/power) plate compactor and a heavy plate compactor in a room of 100x25x5.5 m, respectively (Brouwer, et al., 2001).
Based on the available exposure data and assumptions about the importance of the determinants of exposure, the exposure weights presented in the Table are proposed.

Table 3.3.26 Classes and related exposure weights for activity emission potential of Activity Class 'Compressing of powders, granules or pelletized products'

Description	**Examples**	**Exposure weights**
Compressing more than 1000 kg/minute	Large scale bulk compression of soil or wood pellets	30
Compressing 100 – 1000 kg/minute		10
Compressing 10 – 100 kg/minute		3
Compressing 1 – 10 kg/minute		1
Compressing 0.1 – 1 kg/minute		0.3
Compressing 10 – 100 gram/minute		0.1
Compressing less than 10 gram/minute	Very small scale tabletting, granulation	0.03

Table 3.3.27 Classes and related exposure weights representing process containment during compressing of powders, granules or pelletized material.

Classification	**Examples**	**Exposure weights**
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosed tabletting machine (relatively small openings are possible)	0.3

3.3.4.7 Activity Class: Fracturing of powders, granules or pelletized material

This activity class describes exposure as a result of fracturing of solid products due to crushing. Examples are milling, breaking up granules, crushing of tables in pharmaceutical industry. Published exposure levels are absent and assigned exposure weights are chosen in line with the previous Activity Class.

Table 3.3.28 Emission potential of Activity Class 'fracturing of powders, granules or pelletized material'

Description	**Examples**	**Exposure weights**
Fracturing more than 1000 kg/minute	Large scale bulk milling	30

Fracturing 100 – 1000 kg/minute		10
Fracturing 10 – 100 kg/minute		3
Fracturing 1 – 10 kg/minute		1
Fracturing 0.1 – 1 kg/minute		0.3
Fracturing 10 – 100 gram/minute		0.1
Fracturing less than 10 gram/minute	Very small scale crushing / testing tablets, de-lumping (breaking up products)	0.03

Table 3.3.29 Classes and related exposure weights representing process containment during fracturing of powders, granules or pelletized material.

Classification	**Examples**	**Exposure weights**
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosed tablet crushing (relatively small openings are possible)	0.3

3.3.5 Liquids

The following different Activity Classes are distinguished for liquids: spray application of liquids, activities with open liquid surfaces and open reservoirs, handling of contaminated objects or spreading of liquid products, application of liquids in high speed processes, transfer of liquid products. Weights are assigned for both vapour and aerosol exposure.

3.3.5.1 Activity Class: Spray application of liquids

In this paragraph the activity emission potential of the Activity Class spray application of liquids is described. This represents activities like spray applications of paints, pesticide & biocide spraying, fogging, use of disposable spray cans. Pressure and use rate are important parameters which are interrelated. In addition, worker behaviour is an important driver of exposure in this Activity Class.

Several studies describe the influence of spray application techniques on aerosol formation, both in the context of biocide and pesticide as well as other (paint) applications. A clear distinction can be made between space spraying and surface spraying. The former includes activities like fogging and spraying with aerosol can (e.g. fly spray or air freshener). The latter includes spraying of surfaces using techniques like conventional air-atomization, HVLP, and airless spraying.

Indicator studies showed normalized exposure levels of approximately 1 mg/m^3 for spraying biocides in pest control (low use rate, low pressure) and 3 mg/m^3 for airless spraying of antifouling paint (moderate use rate, high pressure) (van der Jagt et al., 2004; Links et al. 2007). UK HSE (2000) database mentions an exposure to ZnO during spray-painting ranging from 0.5 – 1.3 mg/m^3, with an average of 0.4 mg/m^3 (European Chemicals Bureau, Zinc Risk Assessment Report). An experimental study showed that spraying of high application volumes per time unit led to an increase in inhalable exposure levels (Berger-Preiβ et al. 2005). This study also showed that high pressure spraying and fogging of biocides results in much higher exposure levels as low pressure application techniques; differences of 1 order of magnitude or more were found. This finding is corroborated by Machera et al. (2003) who found a similar factor of 10 between low pressure (3 bar) / low use rate and high pressure (18 bar) / high use rate spraying applications in greenhouses.

The nozzle shape and size are also important in terms of exposure levels and size distribution of the aerosols (Berger-Preiβ et al., 2005). Yet, it is very difficult to clearly distinguish work situations according to this parameter as different types of nozzles are often used at the same workplace.

Proper training and adequate experience are other significant factors, yet difficult to quantify in a generic model. However, the spray direction is a human factor that can be taken into account. It is convincingly shown that overhead spraying causes higher inhalation exposure levels as compared to downward or horizontal directions. Exposure data indicate that upward spraying can lead to an increase in exposure by about a factor of approximately 3 (Berger-Preiβ et al., 2005).

The resulting classification schemes based on the considerations above is described in the following Tables. A distinction is made between surface spraying and spraying in a space. For surface spraying the exposure weights are a multiplication of use rate, spray direction and technique. Due to the interrelation of pressure and use rate, pressure was not taken into account as a separate modifier.

3.3.5.1.1 Activity subclass: surface spraying of liquids

Table 3.3.30 Classes and related exposure weights for surface spraying.

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
High application rate (> 3 l/minute)	Tractor mounted spraying	3	3
Moderate application rate (0.3 - 3 l/minute)	Paint spraying of e.g. ships	1	1
Low application rate (0.03 – 0.3 l/minute)	Pest control operations	0.3	0.3
Very low application rate (< 0.03 l/minute)	Spot spraying using e.g. controlled droplet application	0.1	0.1

Table 3.3.31 Exposure weights for direction of spraying

Description	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**

Spraying in any direction (including upwards)	3	3
Only horizontal and downward spraying	1	1
Only downward spraying	0.3	0.3

Table 3.3.32 Classes and exposure weights for spray technique

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Spraying with high compressed air use	Air blast pesticide spraying of e.g. tree nursery	3	3
Spraying with no or low compressed air use	Paint spraying using HVLP or airless techniques; pest control operations using backpack	1	1

3.3.5.1.2 Activity subclass: spraying of liquids in a space

Table 3.3.33 Classes and related exposure weights for spraying in a space.

Description	**Examples**	**Aerosol exposure weights**	**Vapour exposure weights**
Large scale space spraying	Fogging	10	10
Small scale space spraying	Fly spray	1	1

3.3.5.2 Activity Class: Activities with open liquid surfaces and open reservoirs

For activities with an open degreasing bath approximately one order of magnitude difference was observed in average vapor exposure levels for a small size bath (applicable for machines with loading of 40-50 kg) and large size bath (applicable for machines with loading of more than 1000 kg), with trichloroethylene exposure levels for large bath in excess of 1000 mg/m^3 (von Grote et al., 2003). Dip tanks for furniture stripping of dimensions 8 feet (long) x 3 feet (wide) x 4 feet (high) with 18-34 inch liquid level (50-90% methylene chloride in solution) resulted in exposure levels during immersion of 124 ppm (=431 mg/m^3) for lead stripper and 88 ppm for stripper/washer. Dip tanks were usually covered during soaking with LEV system on dip tank

(McCammon, et al., 1991). These exposure values give an indication that surface area is important although figures are difficult to interpret as the solvent content in the product is often not known.
Based on the above described exposure levels, we propose the following range in exposure weights for vapor exposure depending on surface area in contact with the air: 0.003 – 0.3. The maximum exposure weight being a factor 10 lower as compared to those proposed for spraying. For agitated surfaces, the weights are a factor 3 higher as compared to activities with undisturbed reservoirs.
As expected the exposure to aerosols is much lower in these types of activities. Exposure levels between 0.7 and 78 μg/m^3 were found among workers in nickel plating shops (Kiilumen et al., 1997). The nickel concentration in the plating solutions was on average 63 g l^{-1}. A study of Bright et al. (1997) of chrome and nickel electroplaters showed similar levels of approximately 20 μg/m^3. Chromium exposure levels to chromium measured during electroplating were 10 μg/m^3 (Mäkinen and Linnainmaa, 2004). For agitated surfaces a range in exposure weights is assumed of 0.003 – 0.3. Almost no exposure is assumed for undisturbed baths (0.001).

3.3.5.2.1 Activity subclass: activities with relatively undisturbed surfaces (no aerosol formation)

Table 3.3.34 Classes and related exposure weights for activity emission potential of Activity Subclass 'activities with relatively undisturbed surfaces'

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Open surface > 3 m^2	Tank dipping	0.001	0.3
Open surface 1 - 3 m^2		0.001	0.1
Open surface 0.3 - 1 m^2		0.001	0.03
Open surface 0.1 – 0.3 m^2		0.001	0.01
Open surface < 0.1 m^2	Manual stirring in paint can Storage of laboratory samples	0.001	0.003

3.3.5.2.2 Activity subclass: activities with agitated surfaces

In this activity subclass aerosols of liquid substances arise from activities that agitate the liquid product. Examples of processes are gas bubbling through a fluid and vibration or shaking of a liquid.

Table 3.3.35 Classes and related exposure weights for activity emission potential of Activity Subclass 'activities with agitated surfaces'

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Open surface > 3 m^2	Bath with gas bubbling (e.g. electroplating) Bath with ultrasonic cleaning	0.3	1.0
Open surface 1 - 3 m^2		0.1	0.3
Open surface 0.3 - 1 m^2		0.03	0.1
Open surface 0.1 – 0.3 m^2		0.01	0.03
Open surface < 0.1 m^2	Mechanical mixing in paint can, mechanical mixing very small amounts in e.g. laboratory	0.003	0.01

3.3.5.3 Activity class: Handling of contaminated objects

Very limited published exposure levels are available for this activity class. The exposure weights are chosen in line with activities with open reservoirs (undisturbed).An additional determinant covering level of contamination is taken into account with exposure weights ranging from 0.1 to 1.

Table 3.3.36 Classes and related exposure weights for activity emission potential of Activity class 'handling of contaminated objects'

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Activities with treated/contaminated objects (surface > 3 m^2)	Handling large treated and drying objects	0.001	0.3
Activities with treated/contaminated objects (surface 1-3 m^2)	Maintenance of fuel pumps; coupling and decoupling of hoses or (drilling) equipment	0.001	0.1

Activities with treated/contaminated objects (surface 0.3-1 m^2)	Handling small treated and drying objects	0.001	0.03
Activities with treated/contaminated objects (surface 0.1-0.3 m^2)	Handling of contaminated tools	0.001	0.01
Activities with treated/contaminated objects (surface <0.1 m^2)	Handling small tools in laboratory (e.g. pipettes)	0.001	0.003

Table 3.3.37 Classes and related exposure weights for level of contamination of objects

Description	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Contamination > 90 % of surface	1	1
Contamination 10-90 % of surface	0.3	0.3
Contamination < 10 % surface	0.1	0.1

3.3.5.4 Activity Class: spreading of liquid products

A Finish study focusing on organic solvent exposure during car washing also showed increasing exposure with increasing treated surfaces. Solvent concentrations in the breathing zones ranged from 5 to 465 mg/m^3 during washing of automobiles and 45 to 685 mg/m^3 during the washing of heavy vehicles. Similar exposure levels (>100 mg/m^3) are found for styrene in the reinforced plastic industry when laminating large objects (Nylander-French et al., 1999; Geuskens et al., 1992). Extremely high (>1000 mg/m^3) organic solvent exposure levels were measured while marking and lacquering of parquet (Ludersdorf et al., 1985). Organic solvent exposure levels among shoe repair men involved in gluing of much smaller surfaces were lower with a geometric mean value of approximately 30 mg/m^3 (Hertsenberg et al., 2007). A study of Burstyn and Kromhout (2002) among Dutch painters provide evidence for the fact that rolling and brushing results in less exposure than spraying (factor ~ 5 difference), whereas another study in the styrene industry could not determine a difference between both techniques (Nylander-French et al., 1999). Rolling of antifouling paint (~ 10 % dichlofluanid in paint) in boat yards resulted in mean dichlofluanid levels of 0.01 mg/m^3 (Links et al., 2007). Similar biocide exposure levels (median 0.04 mg/m^3) were found during coating boat hulls by brush and roller (Garrod et al., 2000). Coating of vertical wood surfaces by brush resulted in much higher exposure levels to the product, i.e. median of 1.6 mg/m^3; this high value might be due to splashes rather than true product aerosol (Garrod et al., 2000).

Table 3.3.38 Classes and related exposure weights for activity emission potential of Activity class ‘spreading of liquid products’

Description	Examples	Aerosol exposure weights (incl. powders dissolved in a liquid)	Vapour exposure weights
Spreading of liquids at surfaces or work pieces > 3 m^2 / hour	Painting of walls or ships, removing (large) graffiti, cleaning of oil residue from bulk tanks	0.1	0.3
Spreading of liquids at surfaces or work pieces 1.0 - 3.0 m^2 / hour	Degreasing machines, painting of walls	0.1	0.1
Spreading of liquids at surfaces or work pieces 0.3 - 1.0 m^2 / hour	Painting of casings using a roller or brush, gluing e.g. shoe soles, degreasing or cleaning small machines/tools	0.1	0.03
Spreading of liquids at surfaces or work pieces 0.1 - 0.3 m^2 / hour	Spot degreasing (small objects like knifes), gluing stickers and labels	0.01	0.01
Spreading of liquids at surfaces or work pieces < 0.1 m^2 / hour	Small scale spreading e.g. in laboratory	0.001	0.003

3.3.5.5 Activity Class: Application of liquids in high speed processes (e.g. rotating tools)

Activities that cause liquids to become airborne (aerosols or mist) because of high speed movement of an object (e.g. rotating tools) are grouped in this activity class. Examples of activities are drilling and sawing of metals using metal working fluids, centrifuging wet items, or printing using a rotating press. An important determinant for aerosol formation is the speed of used tools (Heitbrink, et al., 2000). Yet, the exact rotating speed of tools is often not known in a generic assessment.

Many studies were performed investigating the exposure during activities with metal working fluids. Park et al. (2009) performed a literature review to identify the major determinants that may affect exposure. They found that the major factors affecting exposure were decade (year), type of industry, operation and fluid and engineering control measures. One study in workplaces that manufactured automotive parts found exposures to MWF up to 13.5 mg/m^3 with an average exposure of 0.4 mg/m^3 (Park, et al., 2007). Another study among a small sample of workers performing grinding activities had exposures between 0.6-2 mg/m^3 (Park, et al., 2005). Similar levels were found for workers in small machine shops (Ross, et al., 2004). Recently, average personal exposures found when working near enclosed cutting machines was around 0.1 mg/m^3 TWA (Lillienberg, et al., 2008). Similar levels were found in workers in metal working shops in Finland (Suuronen, et al., 2008). Most machines using metal working fluids were enclosed and some level of exhaust was present. Hands et al. (1996) found median exposure levels of 0.21 mg/m^3 among operators of equipment with enclosure and LEV. The exposure level was 0.48 mg/m^3 for machines without enclosures. Yet, it was noted that machines associated with low mist exposure were not enclosed, potentially introducing some bias in the data. Normalized figures suggest exposure levels around 3 mg/m^3.

A study focused on oil mist exposure near shale shakers at off-shore oil drilling platforms found exposure levels around 4.3 mg/m^3 (Steinsvag et al., 2006). Some studies from the 1960’s show mist exposure concentration in printing halls of between 2 - 16.6 mg/m^3 (Hendricks, et al., 1962). Studies in the early 1990’s seem to indicate these levels dropped to below 1 mg/m^3 (Casey, et al., 1983; Leon, et al., 1994). Sources were probably to at least some extent in the far field of the worker during these measurements.

Taking into account the above described exposure levels and contextual information with respect to local controls a base exposure weight of 1 is proposed for aerosol formation during activities like machining with MWF. Given the amount of empirical information it is not considered possible at this stage to distinguish between low and high speed machines. It appears reasonable to assign a weight of 3 for larger scale activities involving high speed movement like large rotating pipes in oil drilling or a large rotating press.

A limited number of studies was found for vapour exposure during activities classified in this Activity Class. For printing activities exposure levels ranged from 19 to 45 ppm of total solvents (Hansen and Whitehead, 1988), which is corroborated by others (Samimi, 1982; Wadden et al.,1995). Wadden et al. (2001) found in-room toluene concentrations between 97 and 464 mg/m^3 around a rotogravure press. A study focusing on exposure levels near shale shakers at off-shore oil drilling platforms found mean exposure levels to oil vapours ranging from 3 mg/m^3 (aromatic content <0.01%), to 36 mg/m^3 (aromatic content 1-10%), and 1217 mg/m^3 (aromatic content ~20 %) (Steinsvag et al., 2006).

The level of vapour exposure is dependent on both the aerosol formation and evaporation from the surfaces. We arbitrarily assign exposure weights to two classes to take into account the scale of the process and the evaporation surfaces involved.

Table 3.3.39 Classes and related exposure weights representing emission potential for high speed processes.

Description	**Examples**	**Aerosol exposure weights**	**Vapour exposure weights**
Large scale activities involving high speed movements	Rotating pipes in oil drilling, rotating press during printing, application of metal working fluids in machining large work pieces	3	3
Small-scale activities involving high speed movements	Application of MWF in machining of small scale work pieces (e.g. < 10 kg)	1	1

Table 3.3.40 Classes and related exposure weights representing process containment during high speed processes.

Classification	**Examples**	**Exposure weights**
Open process: no separation between process and worker		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosing panels around machining process	0.3

3.3.5.6 Activity Class: Transfer of liquid products

This Activity Class represents situations where a stream of liquid is transferred from one reservoir or process to the next. It can be that the liquid stream falls or glides from high to a lower point or is transferred with pressure through hoses or pipes. This stream interacts with air, inducing air currents in and around the stream and release of vapour from the stream. Subsequently, it might induce impaction of the stream at the receiving surface, which again leads to interaction with air and release of droplets (i.e. aerosols). Transfer activities such as loading of a tank, refuelling a car, drumming, pouring, and bottling are included in this Activity Class. Determinants that are relevant for the exposure emission of these activities are use rate and the opening of the tank or bath to which they are transferred. Whereas these determinants have been studied in a quantitative sense for powders, only limited information appears to exist for liquids.

Two important processes have to be distinguished in the transfer of liquids: i.e. evaporation and formation of aerosols. Wolf et al. (1999) studied aerosol generation during three worst case mixing and loading scenarios in an experimental setting. Results indicated that simulated transfer scenarios generated aerosol concentrations between 2.1 and 5.3 ng/l, whereas atomization through nozzles resulted in airborne concentrations of 354 and 96 ng/l. Hence, in normal loading activities aerosol formation is very limited as compared to spraying activities.

The aerosol formation may become more relevant for loading activities with falling liquids with substantial splashing or movement of the liquid. Here a distinction can be made between splash loading and submerged loading, splash filling implies that the liquid dispenser remains at the top of the reservoir and the liquid splashes freely, whereas submerged filling represents a situation where the liquid dispenser remains at the bottom of the reservoir and/or below the liquid surface to minimize exposure (Fehrenbacher and Hummel, 1996). Lewis et al. (1997) and Armstrong et al. (1996) postulated a factor of 3 difference between ‘top splash loading’ and ‘top submerged loading’ of tanker cars. Glass et al. (2001) reported that for drum filling exposure levels for splash loading were a factor 5 higher compared to submerged loading, not taking into account the effect of LEV. These observations suggest that a correction factor of 0.3 for situations where the falling liquid is loaded via a submerged dispenser would be reasonable.

Besides activities with falling liquids, we distinguish activities where the liquid is transferred via a hose or pipe connected to the bottom of the tank or bath, called bottom loading activities. Here we assume that aerosol formation is very limited and exposure mainly occurs through evaporation from the connection point and possible spills after filling. Exposure to vapours might also occur if these are released via an opened manhole on top of the truck when a vapour recovery system is absent.

The exposure weights a few indicator studies can be used. Llewellyn (1996) studied the spray application of a copper containing antifouling paint. Geometric mean inhalation exposure was 0.59 mg/m^3 for sprayers and 0.07 mg/m^3 for fillers. Some of the exposure of the fillers might be due to spraying activities in the worker’s far field. Taking this into account a ratio of 50-100 between spraying and filling with respect to aerosol formation may be plausible and is in line with the exposure study of Wolf et al. (1999). Links et al. (2007) showed only marginally lower exposure levels for paint filling as compared to spraying; however in this study the pot men (responsible for paint filling) were present in close vicinity of the applicators making this figure difficult to interpret.

For both Activity subclasses falling liquids and bottom loading we distinguish 5 categories. For falling liquids these reflect different amounts transferred. A factor 3 was used to represent exposure differences of activities transferring different amounts. Some indications were given by figures showing mean concentrations of total hydrocarbon of 140 mg/m^3 for loading in bulk terminals versus 47 mg/m^3 for barrel fillers (Armstrong et al., 1996).

For splash loading there seems to be little difference between the loading of truck and barges. This is likely because the operator will load several trucks in the time one barge is loaded, when the total loaded volume is kept more or less similar. What likely does affect exposure is the distance an operator will have from the reservoir openings from which the vapour escapes or any possible outlet of the vapour recovery system (Stage I). This is not taken into account in our activity classification since it is covered by correcting for NF or FF exposure source.

Periago et al. (2005) studied service station attendants refuelling cars with gasoline and found that benzene levels before the introduction of vapour recovery systems were approximately a factor 2.5 lower than what was found for road tanker loading. Exposure levels for refuelling by Estevez-Turrillas et al. (2007) and Berglund et al. (1990) were substantially higher than those reported by Periago et al. (2005), but these values were short term peak measurements based on single

samples. For drum loading exposure seems to be substantially higher than for refuelling. No specific exposure data are available for the two lowest categories. These results seem to warrant a distinction between the different categories for splash loading of liquids as they are now defined.
For submerged and bottom loading exposure levels are substantially lower. For truck loading/unloading a factor 5-10 lower exposure levels are observed compared to the same activities using splash loading. Based on the available empirical evidence we propose the exposure weights as indicated in the tables below. We distinguish between exposure weights for bottom filling (no aerosol formation) and falling liquids (aerosol formation).

3.3.5.6.1 Activity subclass: bottom loading

Table 3.3.41 Exposure weights for activity emission potential of Activity subclass 'bottom loading'

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Transfer of liquid product with flow of > 1000 l/minute	Loading of tanker at bulk terminal (boats, rail car or truck)	0.001	0.1
Transfer of liquid product with flow of 100 - 1000 l/minute	Loading of aircraft (under wing)	0.001	0.03
Transfer of liquid product with flow of 10 - 100 l/minute	Transfer of additives in tanker	0.001	0.01
Transfer of liquid product with flow of 1 - 10 l/minute	Transfer of additives in tanker	0.001	0.003
Transfer of liquid product with flow of 0.1 - 1 l/minute	Transfer of additives in tanker	0.001	0.001
Transfer of liquid product with flow of < 0.1 l/minute	Transfer of additives in tanker	0.001	0.001

3.3.5.6.2 Activity subclass: falling liquids

Table 3.3.42 Exposure weights for activity emission potential of Activity Class 'falling liquids'.

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**

Transfer of liquid product with flow of > 1000 l/minute	Loading of tanker at bulk terminal (boats, rail car or truck)	0.1	0.1
Transfer of liquid product with flow of 100 - 1000 l/minute	Filling of drums	0.03	0.03
Transfer of liquid product with flow of 10 - 100 l/minute	(Re)fuelling cars, manual topping up, manual calibration of fuel pump	0.01	0.01
Transfer of liquid product with flow of 1 - 10 l/minute	Filling of bottles, filling of paint gun	0.003	0.003
Transfer of liquid product with flow of 0.1 – 1 l/minute	Filling of bottles, filling of paint gun	0.001	0.001
Transfer of liquid product with flow of < 0.1 l/minute	Transfer of small amounts in laboratory	0.001	0.001

Table 3.3.43 Classes and related exposure weights representing process containment during falling liquids in case of splash loading.

Classification	**Examples**	**Exposure weights**
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Transfer of liquid through a small filling opening (e.g. refuelling of vehicles)	0.3

Table 3.3.44 Classes and related exposure weights representing submerged and splash loading.

Classification	**Exposure weights**
Splash loading, where the liquid dispenser remains at the top of the reservoir and the liquid splashes freely	3.0
Submerged loading, where the liquid dispenser remains below the fluid level reducing the amount of aerosol formation	1.0

3.3.6 Hot or molten metal

The exposure weightings determined by composition and temperature for molten metals will underpin all the weightings presented for the activity classes below (Sections 1 to 5). Containment of the process is dealt with as a risk reduction measure except for smelting, which is always contained, and sintering.

3.3.6.1 Activity Class: (S)Melting

The activity class (s)melting is split into two subclasses: Smelting and Melting.

3.3.6.1.1 Activity Subclass: Smelting

Smelting is considered to be the extraction of metals from metal ore at temperatures that are generally higher then the melting point temperature of the metal.

Exposure weightings are presented for Smelting in the Table below. This deals only with the actual smelting furnace (tapping is dealt with in transfer of molten metals).

The actual smelting process has to be fully enclosed, including the loading/charging operation, and operators spend most of their time in control rooms during routine operation. This means that exposures are possible only during regular control inspections and tapping. Potential determinants such as scale and temperature have little impact on the emissions.

Table 3.3.45 Enclosure-based classes and exposure weights representing smelting processes

Classification	**Example**	**Exposure**
Smelting in an inherently closed process		0.001

3.3.6.1.2 Activity Subclass: Melting

This subclass covers holding and conveying melts (e.g. in a ladle) from one place to another and melting for refining, alloying and casting. This subclass does not include the transfer from molten metal from one vessel to another. Temperature for melting is generally at or just above the melting point of the metal.

The scale of the melting process (mass) is the important determinant of exposure in this subclass and the exposure weights for this determinant are presented in the Table below. Temperature for melting is not an important determinant, as metals are generally only heated to at or just above the melting point.

Table 3.3.46 Scale-based classes and exposure weights representing melting processes

Classification	**Examples**	**Exposure weight**
Large scale melting (> 10 tonnes)	> 10 tonnes	3
Medium scale melting (1-10 tonnes)	1-10 tonnes	1
Small scale melting (100 – 1000 kg)	100 – 1000 kg	0.3
Very small scale melting (< 100 kg)	< 100 kg	0.1

3.3.6.2 Activity Class: Pouring or tapping of molten metals, melt drossing and dipping of workpieces in molten metals

3.3.6.2.1 Activity Subclass: Pouring or tapping of molten metals

This subclass covers the transfer of molten metals from one vessel, furnace or ladle to another and includes drossing of melts. This subclass includes tapping which is the process by which the reduced molten metal (or the slag formed on top of the molten metal layer) is removed from the furnace. This operation usually involves drilling a hole in the furnace enclosure through which the molten metal flows from the furnace via channels which may either be open or covered, and with or without extraction devices in place.

The important determinant for this subclass is the scale of the process and the weights for this determinant are presented in the Table below. Temperature is considered a determinant which distinguishes tapping from a smelting process from that of tapping from a melting furnace.

Table 3.3.47 Scale-based classes and exposure weights for pouring or tapping of molten metal

Classification	Examples	Exposure weight
Large scale pouring or tapping (> 10 tonnes)	> 10 tonnes	10
Medium scale pouring or tapping (1-10 tonnes)	1-10 tonnes	3
Small scale pouring or tapping (100 – 1000 kg)	100 – 1000 kg	1
Very small scale pouring or tapping (< 100 kg)	< 100 kg	0.3

3.3.6.2.2 Activity Subclass: Dipping in molten metal

This subclass includes hot-dip galvanising. The scale of the process and the fluxing of the bath are considered to be the determinants of the emission for this subclass, as temperature is kept at or around the melting point of the metal.

Table 3.3.48 Scale-based classes and exposure weights representing emission from dipping of workpieces into molten metal

Classification	Examples	Exposure weight
Open surface > 3 m^2		3
Open surface 1 - 3 m^2		1
Open surface 0.3 - 1 m^2		0.3
Open surface 0.1 – 0.3 m^2		0.1
Open surface < 0.1 m^2		0.03

Table 3.3.49 The effect of fluxing on exposure weights representing the emission from the dipping bath

Classification	Examples	Exposure weight
No use of flux		1
Use of flux as protective layer on molten metal	Fluxed bath	0.3

3.3.6.3 Activity Class: Sintering, roasting and oxidation/burning

The exposures for this category fall into three different activity sub-classes described in the sections below.

3.3.6.3.1 Activity Subclass: Sintering

This activity class only refers to the sintering of compacted metal powders. Sintering of ore as a precursor to Smelting is included in the activity subclass ‘Roasting’. Especially for metals that have high melting points, sintering (also called “solid state sintering”) is one of the very few possible processing options. Metal powder is first compacted into a mould (for which the related exposures are dealt with under “powder handling”) and subsequently exposed to high temperatures (in the range of up to approximately 2,000 - 3,000 °C). Under sufficient heat, the powder particles begin to bond and finally form one massive metal object. This behaviour can be explained by re-crystallisation processes of the individual particles which subsequently diffuse into the crystal structure of their neighbouring particles.

Because of the hardness of the resulting sintered metal objects, subsequent form giving processes (e.g. drilling) are avoided. Thus, powders are often mixed with “wax-binders”. These mixtures can easily be formed and re-worked prior to sintering. During the sintering process these binders vaporise and the “pure” metal object remains.

Sintering may also be conducted for metal/metal mixtures having lower melting points in order to produce “porous” objects (e.g. for their storage capacity for lubricants in bearings).

The scale of the process is considered to be the important determinant in this subclass.

Table 3.3.50 Scale-based classes and exposure weights representing sintering

Classification	**Examples**	**Exposure weight**
Large scale sintering (> 10 tonnes)	> 10 tonnes	10
Medium scale sintering (1-10 tonnes)	1-10 tonnes	3
Small scale sintering (100 – 1000 kg)	100 – 1000 kg	1
Very small scale sintering (< 100 kg)	< 100 kg	0.3

3.3.6.3.2 Activity subclass: Roasting

In this activity subclass, heat is applied to an ore or concentrate (usually of sulfidic nature) in the presence of oxygen to change the composition from the ore to the metal oxide, and thus represents an essential step prior to the actual smelting process.

Because of the substantial formation of sulfur dioxide, SO_2, and other (potentially highly toxic) metal oxides due to impurities present in the ore/concentrates, this process intrinsically needs to be conducted under full enclosure, with correspondingly low emission potential. Any exposures are not essentially process- or task-related, but instead driven by (minor) breaches or leaks in the system.

Exposure during charging of “cold” ores/concentrates to the roasting furnace are considered to represent “raw material handling” and are not considered under this activity subclass.

During unloading of the finished roasted material from the roasting furnace, either closed or open systems may be used, with corresponding exposure potential. These are usually all large scale operations.

The determinants of emission during this activity class are scale of the process and the type of oven/furnace employed.

Table 3.3.51 Scale-based classes and exposure weights representing roasting

Classification	**Examples**	**Exposure weight**
Large scale roasting (> 10 tonnes)	> 10 tonnes	10
Medium scale roasting (1-10 tonnes)	1-10 tonnes	3
Small scale roasting (100 – 1000 kg)	100 – 1000 kg	1
Very small scale roasting (< 100 kg)	< 100 kg	0.3

Table 3.3.52 Enclosure-based exposure weights representing emission potential for roasting

Classification	**Examples**	**Exposure weight**
Tunnel oven	Tunnel oven,	1
Enclosed roasting furnace	Rotary kiln	0.001

3.3.6.3.3 Activity subclass: Oxidation/burning

This activity subclass refers to operations in which solid metal (usually in the form of ingots) is transferred to a furnace and heated to temperatures well above melting point until the vapours ignite in contact with air, thus forming the metal oxide. Collection of the oxidation product is usually via highly efficient cooling and subsequent bag filter systems which do not give rise to substantial exposures. However, whereas the furnaces employed are routinely fitted with covers, the system may be essentially breached every time solid metal ingots are loaded into the furnace, and during any cleaning/drossing operations. In contrast, other operations may involve fully automated, closed metal loading systems which are usually controlled according to the liquid metal level in the furnace (example: lead oxide production, Penarroya process).
The determinant of emission during this activity subclass is the scale of the process.

Table 3.3.53 Scale effect on emission during oxidation/burning

Classification	**Examples**	**Exposure weight**
Large scale oxidation, burning (> 10 tonnes)		10
Medium scale oxidation, burning (1-10 tonnes)	Production of speciality products, such as high purity oxides	3
Small scale oxidation, burning (100 – 1000 kg)		1
Very small scale oxidation, burning (< 100 kg)	Rotary furnaces	0.3

3.3.6.4 Activity Class: Spray application of hot metal

Thermal spraying is a process whereby metals are deposited in a molten or nearly molten form onto a surface to form a coating[4]. Metal in form of either powders or wires is molten and subsequently sprayed onto a surface where it cools and solidifies. Upon cooling the metal particles applied to the surface undergo a thermal contraction that results in residual stresses in the metallic film. During the spraying process, metal fumes or particles are released into the air.
The two metals most commonly applied by thermal spray are zinc and aluminium, which provide protection in a variety of marine and industrial corrosive environments. The most common methods of thermal spray coating application are: wire flame spraying, powder flame spraying, electric arc spraying, and plasma spraying, which can be characterised as described below.

Flame Spraying (wire or powder)
Wire flame spraying involves using a hand-held gun with an air motor that draws the metal wire into an oxygen-fuel gas flame where it is melted. In powder flame spraying, a metal powder is used to form the coating. The powder is stored in a powder hopper mounted on top of the spray gun. The molten metal is then forced onto the surface by an air blast. Flame spraying achieves

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[4] http://www.arb.ca.gov/coatings/thermal/facility/facilitysurrpt-final.pdf

particle velocities from 40 – 350 m/sec, with deposition rates of 10 – 60 kg/hr (California Environmental Protection Agency, Air Resources Board, 2004).

Electric Arc Spraying

Electric arc spraying involves creating a continuous electric arc between the tips of two wires through the passage of current. Heat from the electric arc melts the wires and an air jet propels the molten metal onto the surface. This process deposit up to 60 kg/hr with particle velocities up to 250 m/sec (California Environmental Protection Agency, Air Resources Board, 2004).

Plasma Spraying

Plasma spraying uses metal powder, and the plasma is produced from the tip of the gun resembling a flame. It is formed by forcing an inert gas through an electric arc within the gun. The metal powder is drawn into the plasma arc cavity by the plasma stream, which also melts the powder, and the plasma jet then propels the molten coating onto the work piece. The plasma process can generate particle velocities greater than 500 m/sec and deposition rates of 5 kg/hr (California Environmental Protection Agency, Air Resources Board, 2004).

High velocity oxy-fuel (HVOF)

This process uses oxygen and a fuel gas to melt the feed powder. HVOF guns have a unique nozzle design that produces extremely high velocity gas to propel molten drops to the part's surface. Particle velocity can reach 1,000 m/sec with deposition rates of up to 5 kg/hr (California Environmental Protection Agency, Air Resources Board, 2004).

Detonation Gun

Powder and gas mixture are fed into a barrel of the detonation gun, where a spark ignites the gas. The resulting explosion melts the powder and propels it at a very high velocity onto the surface being coated. Detonations can occur more than 5 times per second. Particle velocities can reach 800 m/s with a deposition rate of up to 6 kg/hr (California Environmental Protection Agency, Air Resources Board, 2004).

Fume exposure to cobalt, chromium and nickel were around 0.02 – 0.04 mg/m3 for various thermal spraying techniques in the UK. Differences were small between the different techniques (Chadwick et al., 1997).

The exposure determinants for this activity class are deposition rate and particle velocity.

Table 3.3.54 Rate-based classes and exposure weights representing spraying

Classification	**Examples**	**Exposure weight**
Deposition rate > 5 kg/hr	Detonation gun	0.03
Deposition rate < 5 kg/hr	Plasma spraying	0.01

3.3.6.5 Activity class: Atomisation

Metallic powders can be obtained by atomisation of a furnace melt (melt atomisation). This can be achieved by a variety of means such as by spraying molten metal under pressure through a nozzle into a variety of media {liquid atomisation (water or oil) or gas atomisation (air, nitrogen or argon) techniques} and by more specialised techniques including centrifugal atomisation {pouring a melt onto a rotating disc or using the Rotating Electrode Process (REP)}, ultrasound and pressure.

In liquid and gas atomisation, a high energy jet of liquid or gas is injected through an atomising nozzle on to the stream of molten metal. This breaks the stream into droplets which are cooled and solidify before they can deposit on each other or on a surface. This is commercially used for low melting point metals, including lead, zinc, aluminium, tin, cadmium and for ferrous and non-

ferrous alloys. Inert gas and oil atomisation is often used to obtain powders with low oxygen content and eliminates the need for a reduction step after atomisation.
This process requires full enclosure to achieve atomisation and powder formation and the exposure weightings for this are presented in the Table below.

Table 3.3.55 Exposure weighting for atomisation of hot metal

Classification	Examples	Exposure weight
Atomisation in enclosed tank		0.001

3.3.6.6 Activity class: Compressing of, impacting on, or hardening of hot metal objects

This Activity Class represents situations where a heated (below melting point) metal object is compressed, impacted on or hardened. The main type of emission for these processes are fumes emitted from the heated metal, which might be induced by the impaction on or compressing of the metal object. This activity class includes quenching, rolling and forging of heated metal objects.
Quenching refers to the rapid cooling of hot metal objects in a liquid, most commonly used to harden steel. A metal object is heated (but not above melting point) and is subsequently cooled in water, oil or another liquid. The size of the metal object determines the level of fume emission from the object during this process.
Hot rolling is a fabricating process in which the metal is passed through a pair (or pairs) of rolls. There are two types of rolling process, flat and profile rolling. In flat rolling the final shape of the product is either classed as sheet (typically thickness less than 3 mm, also called "strip") or plate (typically thickness more than 3 mm). In profile rolling the final product may be a round rod or other shaped bar, such as a structural section (beam, channel, joist etc). The process is termed as hot rolling if the temperature of the metal is above its recrystallization temperature. If the temperature of the metal is below its recrystallization temperature, the process is termed as cold rolling. During hot rolling, fumes are emitted from the hot metal sheet. The size or surface area of the sheet determines the level of fumes that are emitted during the process.
Forging is the term for shaping metal objects by using localized compressive forces. Hot forging is done at a high temperature, which makes metal easier to shape and less likely to fracture. Warm forging is done at intermediate temperature between room temperature and hot forging temperatures. Forged parts can range in weight from less than a kilogram to 170 metric tons. Forged parts usually require further processing to achieve a finished part. The size of the metal object determines the level of fume emission from the object during this process. Gravimetric analyses of stationary measurements show average total mass levels ranging from 33 to 65 mg/m^3 at different presses (slug and pierce press, draw press, nosing press) (Goldsmith et al. 1976). A similar measurement survey published in the same peer reviewed paper presents total mass levels ranging from 4.6 to 6.2 mg/m^3 (at pierce and nosing presses). It is not described what the proportion of metal exposure was in these gravimetric samples.

Table 3.3.56 Exposure weighting for compressing of, impacting on, or hardening of hot metal objects

Classification	Examples	Exposure weight
Mechanical hot forging, hot rolling or quenching of large scale metal objects	Hot rolling of slabs > 5000 kg Hot forging of metal objects that cannot be lifted by hand (> 50 kg)	10
Manual forging, small scale mechanical	Quenching knives or swords	1

rolling or quenching of smaller sized hot metal objects	Manual forging (e.g. horse smith using hammer and anvil) Hot rolling of rods < 5000 kg

3.3.7 References

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3.4 Localized controls

3.4.1 Definition

Localized controls are defined as engineering control measures in close proximity of the source which are intended to minimize leakage and emission from process, machinery and/or equipment. Localized controls contain and/or capture emitted contaminants before dilution/dispersion in the workplace air can occur, i.e. suppression techniques, containment of the source, and local exhaust ventilation systems.

3.4.2 Scientific background

3.4.2.1 Introduction

The control strategy to reduce occupational exposures is hierarchical and consists of: 1) elimination of the source, 2) reduction of emission, 3) isolation of the source, 4) ventilation to prevent the worker from being exposed, and 5) the use of personal protective equipment to reduce personal exposure levels (Boleij et al., 1995). *Elimination* of the source will not be considered within the Advanced REACH Tool project, because without the source there is no potential for exposure. The use of personal protective equipment is not a form of localized control and is covered as a separate modifying factor (Chapter 3.10).

The emission from the source can be *reduced* by changing the form of the substance (or by changing the process). This can be done by using agents as a paste, flakes or materials in a granular or pelletized form instead of a powder (which is covered by the modifying factor ‘substance emission potential’) or by adding moisture additives to the process. When moisture is added to the substance to change the substance emission potential, this is covered by the modifying factor ‘substance emission potential’. When moisture is added during the process to minimize emission (like wet sawing or grinding), this is considered to be a localized control and is dealt with in this chapter.

Isolation of the source contains the emission by means of material barriers and this can be achieved by containment of the source or by segregating the source from the worker. We consider ‘segregation’ to be a barrier around a source that can physically be entered by a worker (like a room), which is not the case for an enclosure (containment of the source). As a source can be locally controlled (contained, ventilated or suppressed) within a segregated area, containment of the source is considered to be a localized control whereas segregation is treated as a separate modifying factor.

Ventilation is the control of the environment with airflow in order to reduce contaminants to acceptable levels (Goodfellow, 1985). In ventilation, a distinction is made between general ventilation relying on the dilution of workplace atmosphere (which is considered in the modifying factor ‘dispersion’) and local exhaust ventilation, which captures, contains or receives emitted airborne contaminants before dilution/dispersion into the workplace air can occur.

Important elements that determine the effectiveness of localized controls can be differentiated in: 1) technology of the control, 2) procedures, and 3) worker behaviour. The behavioural elements are covered by the modifying factor “worker behaviour” (Chapter 3.7). Although this chapter mainly describes the technology of control measures, the procedural elements (like work protocols, training, and maintenance) are also important for the effectiveness of localized controls. These three important elements are often not independent of each other (e.g. training influences worker behaviour, maintenance affects the technology of the control), and it is therefore complicated to differentiate between these elements. However, for constant effective control measures, the technology of the control should ensure that the influence of procedures and worker behaviour is minimal.

3.4.2.2 ECEL database

Recently, an evidence database was derived from the scientific literature on the effectiveness of Risk Management Measures (RMM) to control inhalation exposure (Fransman et al., 2008). The database is named ECEL (Exposure Control Efficacy Library). Effectiveness of RMM in conjunction with contextual information on study design, sampling strategy and measurement type (amongst other parameters) were stored in an MS Access database. In total 433 effectiveness values for six RMM groups (i.e. enclosure, local exhaust ventilation, specialised ventilation, general ventilation, suppression techniques, and separation of the worker) were collected from 90 peer reviewed publications. These RMM categories were subdivided into more specific categories. Data from ECEL in conjunction with expert judgement was used for the underpinning of the assigned scores.

3.4.2.3 Different types of localized controls

Reduction of emission: Suppression techniques
Suppression techniques are defined as techniques where an additive is added to a product, an activity or process in an attempt to suppress emissions from the source. This is normally done by adding water to the process, but other liquids such as chemicals, oils and foams have also been used.
As regards suppression techniques, we define three stages in time:

- **Wetting before emission.** Wetting of the source before emission occurs is not considered to be a localized control measure. When moisture is added to the substance before the beginning of the process in order to change the substance emission potential, this is covered by the modifying factor ‘Substance emission potential’ (Chapter 3.2).
- **Wetting during emission.** When moisture is added during the process at the point of release (like wet sawing or grinding), this is considered to be a localized control. Although this is usually done to cool the saw blade or grinding wheel, it subsequently reduces airborne dust. This type of control is called “suppression at the point of release”. This approach is most effective against high (> 10 mg/m^3) dust concentration emission levels.
- **Wetting after emission.** When airborne contaminants are damped down or knocked down after they have been released into the work environment, this is called knockdown suppression (post generation suppression). This type of control is not commonly used and is far less effective than suppression at the point of release.

Spray systems at transfer points and on material handling operations have been estimated to reduce emission 70 to 95 % (EPA, 1995). It is usually better to aim sprays at the material/blade interface than at the dust cloud produced by cutting (NIOSH, 2003). Water sprayed into the dust cloud reduces airborne dust levels by no more than 30% (Courtney and Cheng, 1977). Airborne dust reductions can be improved by raising the water pressure (Jayaraman and Jankowski, 1988). However, water that is sprayed into a dust cloud can create an airflow that moves the contaminated air instead of reducing the emission, which can (under unfortunate circumstances) increase personal exposure levels (NIOSH, 2003). Some efforts have been made to increase the capture effectiveness of sprays by reducing the droplet size. This includes technologies such as atomizing or fog sprays, steam, sonically atomized sprays, compressed air- atomized sprays, and electrically charged atomized sprays (Bigu and Grenier, 1989; McCoy et al., 1983). Although these methods usually offer a somewhat better dust reduction, they have many disadvantages that prevent their use in industrial settings: smaller nozzle sizes are more prone to clogging and fine droplets are likely to evaporate quickly (McCoy et al., 1983).

Foam has been found to be more effective at dust reduction than water and provides increased dust reductions of 20 to 60 % (Seibel, 1976; Mukherjee and Sigh, 1984; Page and Volkwein, 1986). The drawback of the use of foam for dust control is high cost.

Isolation of the source: Containment (without extraction)

A source can be contained to isolate the (chemical) substance and therefore minimize the emission levels from the source. The concentration of hazardous material inside the containment may be very high and proper provision must be made to clean, purge and test the containment before it is breached. If complete containment is relied upon as the only method of control, it must be strong enough to remain dust or gas tight under all conditions of working unless proper provision is made to vent or release any excess pressure safely (BOHS, 1987). Containment without extraction is not widely used as a measure to reduce airborne concentrations. However, if the containment is not opened during the given activity or work-shift (e.g. a lid on a can of solvent) it can be an efficient way of minimizing levels of airborne contaminants. To be efficient in reducing emissions and prevent leakage from the source the containment must be fully closed. This does not necessarily mean that the containment needs to be completely gas tight, but it must not be breached during the given activity. From a modelling perspective, if the containment is breached, this time should either be treated as a separate activity or the entire activity should be treated as non-contained.

As supported by the results of ECEL database, partial containment without any form of local ventilation is not an effective way of reducing emission levels, with the effectiveness for partial enclosure ranging from 10 to 35 % reduction in exposure (Fransman et al., 2008). Therefore partial containment is not treated as a separate (sub)class of localized controls.

Three levels of containment are defined:

- **Low level containment**: Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The process is contained with a loose lid or cover, which is not air tight. This includes tapping molten metal through covered launders and placing a loose lid on a ladle. This class also includes bags or liners fitted around transfer points from source to receiving vessel. These include Muller seals, Stott head and single bag, and associated clamps and closures.
- **Medium level containment**: Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The material transfer is enclosed with the receiving vessel being docked or sealed to the source vessel. Examples include sealing heads, transfer containers and multiple o-rings. Inflatable packing head with continuous liner ensures a seal is maintained during the powder transfer and the continuous plastic liner prevents direct contact with the product. The correct type of tie off must be used.
- **High level containment**: Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The substance is contained within a sealed and enclosed system. This class includes metal smelting furnaces or atomisation units. The material transfer is entirely enclosed with high containment valves (e.g. split butterfly valves and direct couplings, which consist of two sections which connect together to allow the opening of the valve). At the end of the material transfer the two halves are separated, forming a seal on both the process equipment and the material container. The system is designed to minimise the surface area which can contact the material or pairs of valves with wash space between them.

Ventilation of the source: Local ventilation systems

Local ventilation hood types can be divided in three types (HSE, 2008):

- **Receiving hoods:** The process usually takes place outside the hood. The hood receives the contaminant cloud, which has a speed and direction that is usually process-generated (e.g. a canopy hood over a hot process, grinding wheel and receiving hood) (Figure 3.4.1) (HSE, 2008). Receiving hoods include the push-pull systems.
- **Capturing hoods:** The process, source and contaminant cloud are outside the hood. A capturing hood has to generate sufficient airflow at and around the source to 'capture' and draw in the contaminant-laden air. A capturing hood may be appropriate when the contaminant cloud has no strong and predictable speed and direction. Capturing hoods can be fixed or moveable (Figure 3.4.2) (HSE, 2008) and include on-tool extraction (Low Volume High Velocity (LVHV) extraction).
- **Enclosing hoods:** The benefit of a combination of enclosure with LEV is that the enclosure usually does not have to be as substantial as is required for complete enclosure. Also the exhaust system can be of modest proportion if the openings of the partial enclosure are kept as small as practicable. A full enclosure is where the process is completely enclosed, e.g. a glove box or glove bag. A partial enclosure contains the process with openings for material and/or operator access, e.g. fume cupboards (Figure 3.4.3) (HSE, 2008).

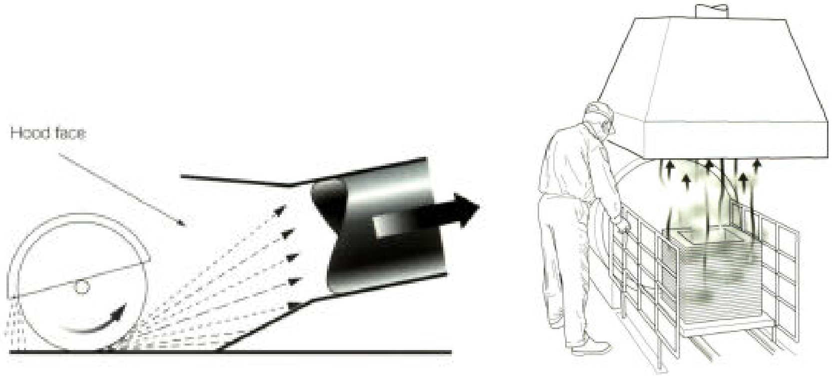


Figure 3.4.1 Receiving hoods (HSE, 2008). (Right: canopy hood over a hot process)

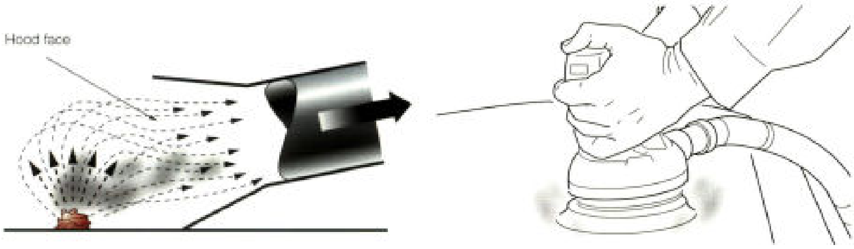


Figure 3.4.2 Capturing hoods (HSE, 2008). (Right: LVHV on-tool extraction)

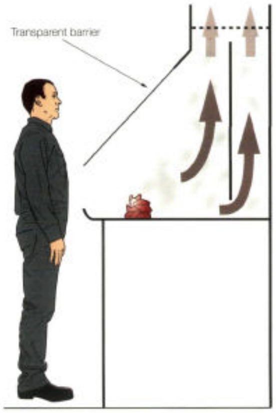


Figure 3.4.3 Enclosing hood (HSE, 2008)

In order to be effective, the capture velocity (velocity induced near the source of the contaminant which is necessary to ensure the capture of the pollutant) of a local ventilation system must be large enough to overcome the movement of the contaminant and any opposing air currents (draughts). The capture velocity together with the capture distance determines the 'capture zone' of the hood. To be effective in reducing individual exposure levels, the capture zone must cover the 'working zone' (i.e. the location where emission occurs) (HSE, 2008), which is the 'local control influence region' (LCIR) of the conceptual model as described by Tielemans et al (2008). Capturing hoods can be either fixed or movable (Figure 3.4.2). For fixed hoods, the working zone must be adjusted to match the capture zone. For movable captor hoods, the capture zone (positioning of the hood) must be adjusted to the working zone. In general, the capture zone of the ventilation system must be large enough to cover the working area and should be known by the worker (the capture zone could be defined and marked out). As a rule of thumb, at one hood diameter out from the face of the capturing hood, the air velocity has fallen to about one tenth of the face velocity (HSE, 2008). The capturing hoods may less effective due to one or more of the following:

- the capture zone being too small;
- the capture zone being disrupted by draughts;
- the capture zone not encompassing the working zone;
- the nature of the task moving the working zone out of the capture zone;
- the capture effectiveness being over-estimated;
- a lack of information about the capture zone size. (HSE, 2008)

In addition, the effectiveness of capturing hoods depends on the activity or process that is performed in front of the hood with "quiet" sources being more efficiently controlled than "highly energetic" sources.

A specific type of capturing hood is LVHV, which utilises a small hood with a high face velocity (e.g. 100 m/s), located very close to the source. Typically, LVHV is applied in hand-held tools (like in a rotary sander, grinding wheels, etc.) (HSE, 2008). Based on information from the ECEL database it was concluded that this integrated type of on-tool extraction was very efficient in reducing exposure levels (estimated average effectiveness = 87%) (Fransman et al., 2008).

The amount of exhaust air that is needed for any enclosing hood will depend on the total area of all the openings into the enclosure and on the velocity of the entering air (BOHS, 1987). The velocity of the air entering the openings must be such that it will overcome any tendency for the contaminated air to escape the enclosure. This tendency is influenced by many conditions inside and outside the enclosure such as moving machinery, generation of heat, draughts, etc. Draughts can impair the effectiveness of hoods, and in industrial settings draughts can reach up to 0.3 m/s. Consequently, a hood face velocity of at least 0.4 m/s is required in most workrooms to overcome the effects of draughts (HSE, 2008). To ensure effective control, the air entering the hood must overcome all other air movements and maintain an inward flow under all conditions of working (BOHS, 1987).

According to the above classification of LEV systems, glove boxes and glove bags are considered to be a form of enclosing hoods. However, for practical reasons and user friendliness of the Advanced REACH Tool, we made a separate class, which contains glove boxes and glove bags. Different types of glove boxes and glove bags are defined:

- **Glove box**: Any form of permanent encapsulation or encasing of the source (which are not opened during the given activity) with a well designed local exhaust ventilation system. The design of both the enclosure and the ventilation system is such that the influence of worker behaviour is minimal (e.g. the enclosure cannot be opened before the substance is properly vented).
    - *Low specification glove box* (Single chamber; Simple access doors or pass box; Not safe change glove; Single HEPA filtered extract air; Not safe change filters; Manual cleaning).
    - *Medium specification glove box* (Two or more chambers if large area bin docking or high dust levels expected; Safe change or push through filters are required; Solid (stainless steel) construction for durability; Size is dependent on the task to be carried out; Safe change filters are required; Air should be single or double HEPA filtered and or exhausted directly to the atmosphere after single HEPA filtration; The equipment should be maintained under negative pressure and the air flow and filter condition continuously monitored; Emergency air extraction should start up automatically in the event of a leak or a damaged glove; Interlocked air locks should be used to prevent high dust concentrations in the area of the transfer ports and reduce risk (escape of the contaminant during transfer of materials into and out of the glove box); Glove changes should be able to be carried out without breaking containment; Waste disposal ports are required. Correct sealing of continuous liners; Manual cleaning).
    - *High specification glove box* (Two or more chambers; Safe change filters are required; Stainless steel construction; Size is dependent on the task to be carried out; Safe change filters are required; Air should be single or double HEPA filtered and or exhausted directly to the atmosphere after single HEPA filtration; The equipment should be maintained under negative pressure and the air flow and filter condition continuously monitored; Emergency air extraction should start up automatically in the event of a leak or a damaged glove; Interlocked air locks should be used to prevent the escape of the contaminant during transfer of materials into and out of the glove box; Glove changes should be able to be carried out without breaking containment; Waste disposal ports are required; Integrated sampling and contained drum charging; Sealed and high containment transfer ports (contained transfer couplings, rapid transfer ports (RTPs), alpha/beta valves etc.); Including waste removal and change parts; Wash in place; Alarmed).
- **Glove bags***:* Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way. An adaption piece is necessary between the glove bag and the process equipment. The glove bag must be designed specifically for the task and the quantity of material to be handled. Various other items such as pass-out boxes, inlet filters, and drains are added to meet specific needs. Note: use of glove bags does not negate the need to implement a long term permanent technological solution.
    - *Glove bags (non-ventilated):* Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way without exhaust ventilation.

- o *Glove bags (ventilated or kept under negative pressure)*: Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way. The glove bag is maintained with filtration and ventilation at specific flow rates.

Vapor control is the process of collection and/or recovering the vapors of gasoline and other (volatile) liquids or gases so that they do not escape into the environment. A vapor control system exists of equipment to collect vapor and possibly a device for reduction of the vapor concentration, either by recovering the hydrocarbons back to liquid or by destroying them, e.g. in an incinerator. Vapor collection is initiated by the transfer of the liquid, which results in the passive transfer of the same volume of vapors back to the tank (Saarinen, 2000; Institute of Petroleum, 2000).

When the product cycle of gasoline is taken as a starting point, the following stages with regard to vapour collection can be identified (Institute of Petroleum, 2000) (see Figure 3.4.4):

- Stage 1: reduction of emission during storage, loading and off-loading
  - 1a: the collection of vapor emissions during gasoline storage and loading at a refinery or terminal
  - 1b: the collection of vapor emissions during the filling of a storage tank at a service station
- Stage 2: the collection of vapor emissions during the filling of a fuel tank of a vehicle.

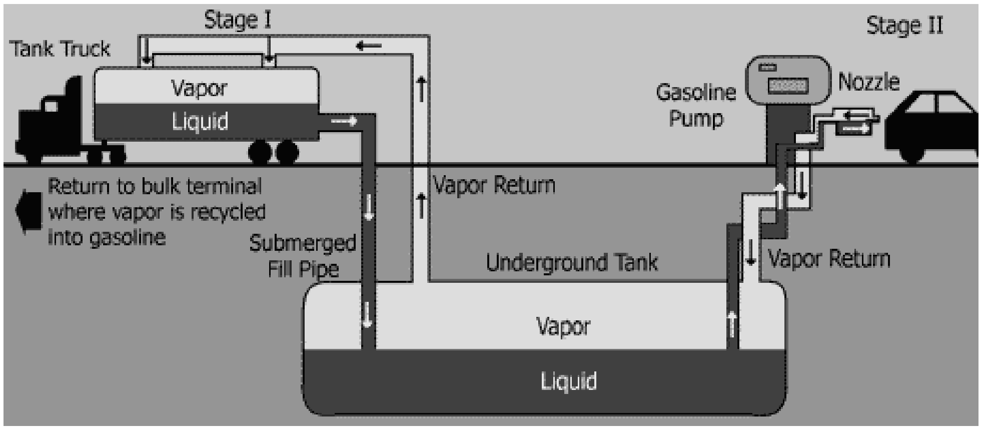


Figure 3.4.4 Stage I and II vapour collection systems

After an inventory and appraisal of existing RMM for use in REACH registration of petroleum substances, the ECEL database was supplemented with data on the effectiveness of RMM for this particular branch. This data mainly comprised information on the effectiveness of vapour collection systems. Based on information from the ECEL database it was concluded that vapour collection systems are very efficient in reducing exposure levels, with an estimated median effectiveness of 80%. This effectiveness assumes that the vapor collection system is properly used, which means that the transfer system is fully closed and no vapor can escape through other openings like open manholes or pressure valves. (Berglund, 1990; Carter, 2002; Cecil, 1997; Hakkola, 2000; Halder, 1986; Rappaport, 1987; Saarinen, 2000; Saarinen, 2002; Smith, 1993; Verma, 2004).

Spray rooms (booths or cabins) may be considered as a particular form of enclosing hoods. However, because both the worker and the source are located inside the booth/room/cabin, we consider this type of control to be room ventilation (displacement ventilation), which is included in the modifying factor “dispersion” (Chapter 3.9). Therefore, spray rooms are not part of the modifying factor “localized controls”.

To reduce exposure levels, the positioning of the worker relative to the source and the ventilation system is crucial in the effectiveness of the ventilation system (HSE, 2008). This should largely be covered by a proper design of the system, but the behaviour of an individual worker can also strongly influence the effectiveness of the ventilation system.
Any local ventilation system should be regularly checked and well maintained. Although we consider this to be normal practice, this is crucial in maintaining a good effectiveness of local ventilation systems. The Health and Safety Executive (HSE) supply useful recommendations in guidance HSG 258 “Controlling airborne contaminants at work” (HSE, 2008), such as the implementation of user manuals, air-flow indicators and labelling of hoods during examination.

3.4.3 Proposal for classification scheme

The effectiveness of localized controls is usually measured under experimental conditions. This measured effectiveness can deviate from the real working conditions due to the behaviour of the worker, but also due to all sorts of working or environmental conditions. This means that there is a huge range in the “true effectiveness” of localized controls and that their effectiveness in the work environment is usually lower than the measured experimental effectiveness. This was also concluded from the evaluation of the ECEL database, which showed a three times better effectiveness for studies with an experimental design compared with cross-sectional study designs (Fransman et al., 2008). On the other hand, the measured true effectiveness of localized controls in the cross-sectional study design could also be distorted by other factors which are not directly related to the control, like a slight difference in activity or use rate of the substance before and after the implementation of the control measure. Therefore, effectiveness of localized controls, which has been measured under different conditions (experimental or cross-sectional), should be interpreted with caution when estimating the true effectiveness of localized controls for exposure modelling purposes.

The proposed values for the effect of localized controls have been found to be similar for all types of exposures (dusts, fibres, vapours, gases, etc.) (Fransman et al., 2008). For that reason, the effectiveness of localized controls is treated the same for all types of contaminants.

The values presented in the table are typical values for the effectiveness of the described localized controls. As described in the introduction section of this chapter, important elements that determine the effectiveness of localized controls are not only the technology of the control, but also procedural elements (like training, maintenance, etc.). The effectiveness of the controls can therefore deviate from this typical value based on differences in: 1) technology, 2) maintenance, 3) administrative factors (like training and user manuals). In addition to the typical value for the effectiveness of controls, a “best practice” value could be given to describe the maximum achievable effectiveness; this represents the effectiveness with the highest degree of technology, maintenance, and training. The best practice value will not be incorporated in the current ART version. Similarly, a “worst practice” value could be given to describe the minimal effectiveness of a control system. However as this minimum value will practically always be 1 (0% reduction), this worst practice value is not included in the assignment of effectiveness values.

Table 3.4.1 Proposed classification of localized controls and assigned values

No localized controls

Localized control subclass	Description	Assigned typical value[#]	Examples
No localized controls	No control measures in close proximity of the source.	1	

[#] A value of 0.1 is equivalent to a 90% reduction in personal exposure level

Suppression techniques

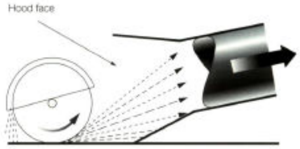
Localized control subclass	Description	Assigned typical value$^{\#}$	Examples
Wetting at the point of release	Wetting systems that wet the process at the point of release (focusing on the emission source) to agglomerate and bind the fine particles to prevent dust from being dispersed into the workroom air.	0.1	Wet grinding, rock crushing, wet drilling.  Thorpe et al, 1999: “Wetting at the point of release”
Knockdown suppression	Post generation suppression of airborne contaminants to reduce dust levels. Knockdown of a contaminant after it has been emitted.	0.7	Water wash curtain, electrostatic capture, misting (steaming), damping down spray.

Containment – no extraction

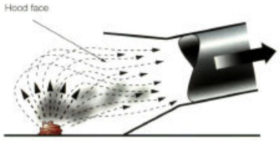
Localized control subclass	Description	Assigned typical value$^{\#}$	Examples
Containment - no extraction	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. This class reflects “add on” enclosures and does not include inherently closed systems (like pipelines)		
- Low level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The process is contained with a loose lid or cover, which is not air tight. This includes tapping molten metal through covered launders and placing a loose lid on a ladle This class also includes bags or liners fitted around transfer points from source to receiving vessel. These include Muller seals, Stott head and single bag, and associated clamps and closures.	0.1	

- Medium level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The material transfer is enclosed with the receiving vessel being docked or sealed to the source vessel. Examples include sealing heads, transfer containers and multiple o-rings. Inflatable packing head with continuous liner ensures a seal is maintained during the powder transfer and the continuous plastic liner prevents direct contact with the product. The correct type of tie off must be used.	0.01	
- High level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The substance is contained within a sealed and enclosed system. This class includes metal smelting furnaces or atomisation units. The material transfer is entirely enclosed with high containment valves (e.g. split butterfly valves and direct couplings, which consist of two sections which connect together to allow the opening of the valve). At the end of the material transfer the two halves are separated, forming a seal on both the process equipment and the material container. The system is designed to minimise the surface area which can contact the material or pairs of valves with wash space between them.	0.001	

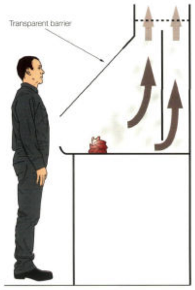
Local ventilation systems

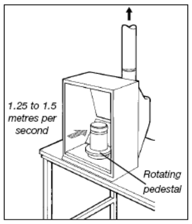
Localized control subclass	**Description**	**Assigned typical value**$^{\#}$	**Examples**
Receiving hoods			
Canopy hoods	A canopy hood placed over a hot process to receive the plume of contaminant-laden air given off. For cold processes with no thermal uplift, canopy hoods are ineffective (HSE, 2008).	0.5	 Canopy hood over a hot process (HSE, 2008)
Other receiving hoods	A receiving hood can be applied wherever a process produces a contaminant cloud with a strong and predictable direction (e.g. a grinding wheel). The contaminant cloud is propelled into the hood by process-induced air movement. The face of the hood must be big enough to receive the contaminant cloud and the extraction empties the hood of contaminated air at least as fast as it is filled.	0.2	 Grinding wheel and receiving hood (HSE, 2008)

Capturing hoods

Fixed capturing hoods	Fixed capturing hoods located in close proximity of and directed at the source of emission. The design is such that the work is performed in the capture zone of the ventilation system and the capture is indicated at the workplace.	0.1	 Capturing hood (HSE, 2008)
Movable capturing hoods	Movable LEV systems such as hoods with extendable arms. The design of the system does not prevent work being performed outside the capture zone of the system and worker behaviour can influence the effectiveness of the system.	0.5	 Movable capturing hood (HSE, 2008)
On-tool extraction	LEV systems integrated in a process or equipment that cannot be separated from the primary emission source.	0.1	 On-tool extraction (HSE, 2008)

Enclosing hoods

Fume cupboard	Any form of permanent encapsulation or encasing of the source of which maximally one side is open with a well designed local exhaust ventilation system (e.g. laminar air flow). The design of both the enclosure and the ventilation system is such that the influence of worker behaviour is minimal (e.g. an alarm system prevents the worker from using the fume cupboard in case the system is not working properly).	0.01	 Fume cupboard (HSE, 2008)
Horizontal/downward laminar flow booth	In a horizontal laminar flow booth, contaminated air is extracted through holes situated at the rear of the booth which creates a horizontal laminar air flow. The air is filtered prior to being discharged to the atmosphere. The booth contains the source and has maximally one side open. In a downward laminar flow booth, a curtain of descending laminar air flow is created between the ceiling and the rear of the booth where exhaust grills are located in the lower section. The booth contains the source and has maximally one side open.. Spray rooms and laminar down-flow booths (with the size of a room which contains both the source and the worker) are not considered to be a localised control and will be treated together with the dispersion questions at a later stage.	0.1	

Other enclosing hoods	Any form of permanent encapsulation or encasing of the source of which maximally the front side is open with a proper local exhaust ventilation system.	0.1	 Spraying glazes and colours (http://www.hse.gov.uk/pubns/guidance/cr5.pdf)
Other LEV systems	In case the type of local exhaust ventilation system is unknown or not specified, this default LEV category can be selected. Note that this default category results in a low reduction of the estimated personal exposure level. An attempt should be made to more specifically define the type of local exhaust ventilation.	0.5	

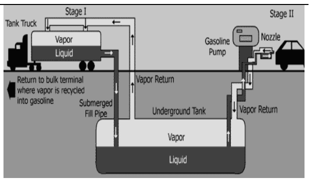
Glove bags and glove boxes

Localized control subclass	**Description**	**Assigned typical value**#	**Examples**
Glove bag	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way. An adaption piece is necessary between the glove bag and the process equipment. The glove bag must be designed specifically for the task and the quantity of material to be handled. Various other items such as pass-out boxes, inlet filters, and drains are added to meet specific needs. Note: use of glove bags does not negate the need to implement a long term permanent technological solution.		
> Glove bag (non-ventilated)	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way without exhaust ventilation.	0.01	
> Glove bag (ventilated or kept under negative pressure)	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way. The glove bag is maintained with filtration and ventilation at specific flow rates	0.001	
Glove box	Any form of permanent encapsulation or encasing of the source (which are not opened during the given activity) with a well designed local exhaust ventilation system. The design of both the enclosure and the ventilation system is such that the influence of worker behaviour is minimal (e.g. the enclosure cannot be opened before the substance is properly vented).		

> Low specification glove box	A low specification glove box is specified as: • Single chamber, simple access doors or pass box • Not safe change glove • Single HEPA filtered extract air • Not safe change filters Manual cleaning	0.001
> Medium specification glove box	A medium specification glove box is specified as: • Two or more chambers if large area bin docking or high dust levels expected • Safe change or push through filters are required • Solid (stainless steel) construction for durability • Size is dependent on the task to be carried out • Safe change filters are required • Air should be single or double HEPA filtered and or exhausted directly to the atmosphere after single HEPA filtration. • The equipment should be maintained under negative pressure and the air flow and filter condition continuously monitored. • Emergency air extraction should start up automatically in the event of a leak or a damaged glove. • Interlocked air locks should be used to prevent high dust concentrations in the area of the transfer ports and reduce risk. (escape of the contaminant during transfer of materials into and out of the glove box). • Glove changes should be able to be carried out without breaking containment • Waste disposal ports are required. Correct sealing of continuous liners. Manual cleaning	0.0003
> High specification glove box	A high specification glove box is specified as: • Two or more chambers • Safe change filters are required • Stainless steel construction • Size is dependent on the task to be carried out • Safe change filters are required • Air should be single or double HEPA filtered and or exhausted directly to the atmosphere after single HEPA filtration. • The equipment should be maintained under negative pressure and the air flow and filter condition continuously monitored. • Emergency air extraction should start up automatically in the event of a leak or a damaged glove. • Interlocked air locks should be used to prevent the escape of the contaminant during transfer of materials into and out of the glove box. • Glove changes should be able to be carried out without breaking containment • Waste disposal ports are required.	0.0001

	• Integrated sampling and contained drum charging • Sealed and high containment transfer ports (contained transfer couplings, rapid transfer ports (RTPs), alpha/beta valves etc.) • Including waste removal and change parts • Wash in place Alarmed		

Vapor recovery systems

Localized control subclass	**Description**	**Assigned typical value**[#]	**Examples**
Vapour recovery systems	Reduction of vapour emission during storage, loading and off-loading of gasoline or other liquids, and during re-fuelling of a vehicle, by the combination of a vapour collection system and a vapour control unit. Vapour collection is a passive process where the volume of liquid transferred is equal to the volume of vapour transported back to the tank. The system only works properly when no other escape openings are present.	0.2	

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3.5 Segregation

3.5.1 Definition

Segregation of the source is defined as isolation of sources from the work environment in a separate room without direct containment of the source itself.

3.5.2 Scientific background

Segregation can be used for controlling the risks from toxic materials, though it is so simple and obvious that it may well be overlooked in plans for a comprehensive occupational hygiene programme (Harvey, 1995). Segregation is very similar to enclosure (see Modifying Factor ‘Localized controls’) in that segregation also isolates the emission source from the worker by means of material barriers. The difference is that a segregated area is big enough for the worker to be able to physically enter the segregation (e.g. a separate room with the source). In fact, within a segregated area a source can additionally be enclosed and/or ventilated.

The efficacy of segregation has not been extensively studied in the occupational hygiene field, as is confirmed by the fact that the literature search for the ECEL database did not result in any peer-reviewed publications on the efficacy of segregation in occupational industrial settings (Fransman et al., 2008). However, the work that has been done in studying environmental tobacco smoke leakage from smoking rooms or in office buildings (Wagner et al., 2004; Ott et al., 2003; Liu et al., 2001; Miller and Nazaroff, 2001) can be used to estimate the effect of segregated work spaces on personal exposure levels. From these surveys it was concluded that the most important factors for a segregation to be effective in reducing exposure levels in adjacent rooms were: 1) full floor-to-true-ceiling walls, 2) no return air from the segregated area (with emission source) to adjacent work areas, 3) exhaust from the segregated area (with emission source) to the outside (not to adjacent areas), and 4) maintain a negative pressure in the segregated area compared with adjacent areas (Liu et al., 2001; Wagner et al., 2004). Liu et al. (2001) reported that if these criteria were met, the concentration of nicotine, sulphur hexafluoride (SF_6), and fluorescent particulate matter (FPM) in adjacent room air ranged from 1 to 10 percent of the concentration in the segregated area. These results are corroborated by Miller and Nazaroff (2001) who also found a 90-95% reduction in concentration in the adjacent work area compared with the segregated smoking room.

Segregation can, by definition, only apply to a far field source, because of the dimensions of the segregation and the consequent distance between the source and the breathing zone of the worker. Hence, there is no near field source in case of segregation. In case the worker enters the segregation or is working within the segregated area, this segregated area is considered to be the work area and ‘segregation’ does no longer apply to the activity.

Another factor that influences the efficacy of segregated rooms is the swing pumping action when the door opens. The exchange volume for a standard door was measured to be around 50% of the volume swept by the door as it opened and closed (Wagner et al., 2004; Kiel and Wilson, 1989). This is taken into account in the classification and assigned value of partially segregated rooms. Ott et al. (2003) found that two adjacent rooms with an open door between them with no ventilation system operating behaved as a single compartment.

The segregated area with the source needs to be in the same department as the worker (see Figure 3.5.4), which is in line with the definition of the far field. In a large production facility, there can be a large distance between the source and the worker, which will be covered by the modifying factor ‘dispersion’.

Segregation can be an intentional control measure to reduce exposure levels (by design placing a source in a separate room), but in most cases segregation will be a way to model the effect of the source being located in a separate space (e.g. room, work area) as described in the paper on the conceptual model (Tielemans et al., 2008).

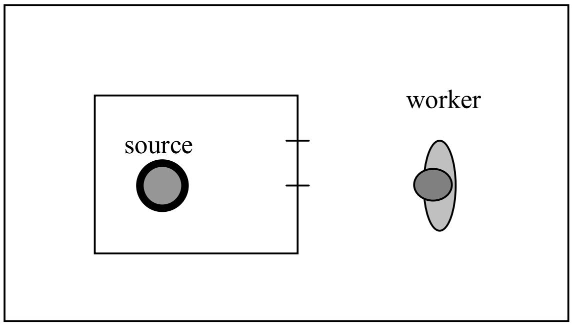

Figure 3.5.1 Complete segregation (doors and windows closed)

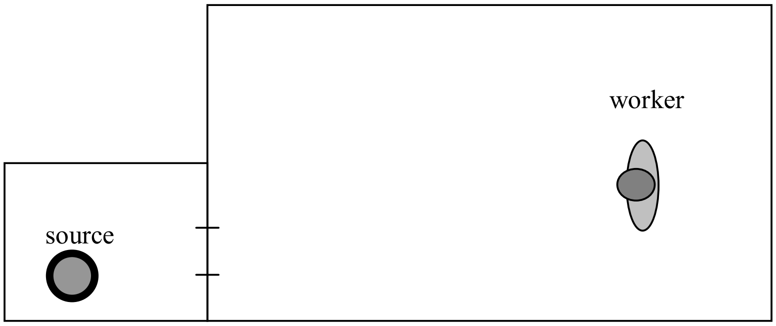

Figure 3.5.2 Complete segregation (doors and windows closed)

Segregation can be either complete or partial (see Figures 3.5.1, 3.5.2, and 3.5.3). Complete segregation means that the source is in a separate enclosed area from the worker, but big enough for the worker to physically enter the separate room. A room that is not connected (i.e. no door or opening) to the work area of the worker is not considered to be a segregation (see Figure 3.5.4).

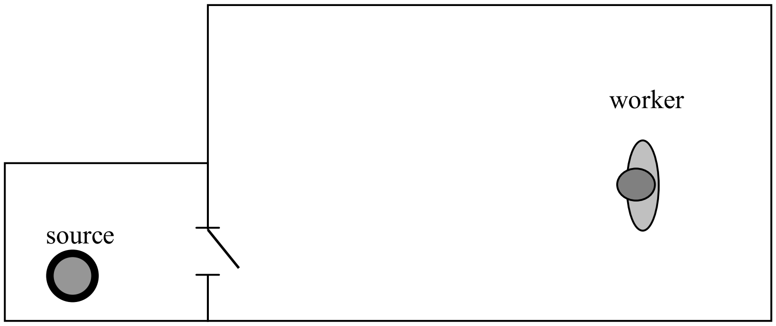

Figure 3.5.3 Partial segregation (doors and/or windows open)

For complete segregation the room must be physically closed (windows and doors shut) during the entire activity, but does not necessarily needs to be completely sealed air-tight. Partial segregation is similar to complete segregation, but then with the door (window open, gap without door) opened (see Figure 3.5.3). The opening between the room with the source and the area where the worker is, should not be larger than a door or a window (see Figure 3.5.5). If the door or window of the segregation is open during part of the activity time, the source should be considered to be partially segregated during the entire activity. In case a source is shielded with curtains or screens that do not reach the ceiling of the area and without a roof or cover on top, this is not considered to be a segregated area.

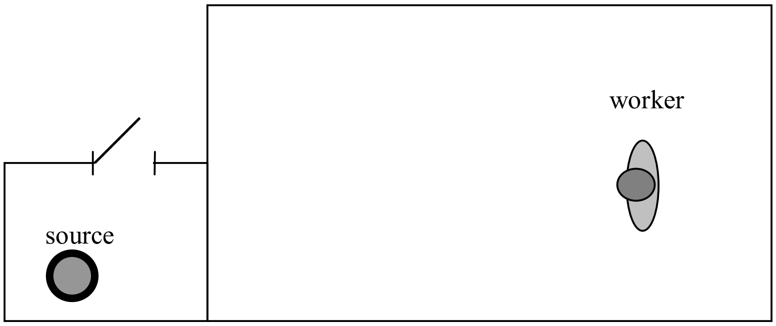

Figure 3.5.4 No segregation (source is in another department)

Like enclosing hoods (see chapter 3.4: "Localized Controls"), the area in which the source is located can be actively ventilated to reduce the emission levels. In case of localized control (e.g. a capture hood), this will be dealt with in the modifying factor for localized controls. Any general ventilation inside the segregated room is believed to be less effective compared with ventilation inside an enclosure (BOHS, 1987).

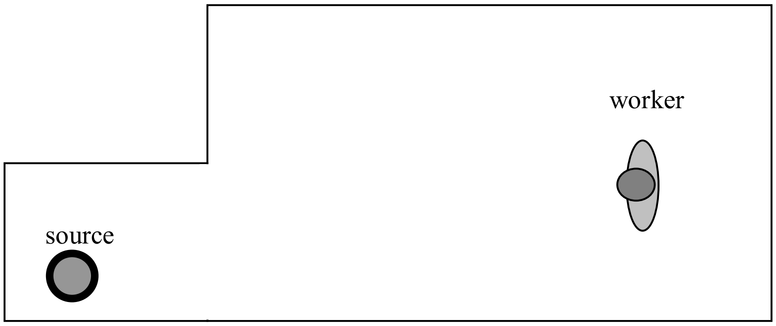

Figure 3.5.5 No segregation (opening between source and worker is larger than a door or window)

3.5.3 Proposal for classification scheme

Any general ventilation inside the segregated room is believed to be less effective compared with ventilation inside an enclosure, which is usually tighter around a source (BOHS, 1987). We therefore consider the assigned values for segregation (with ventilation) to be somewhat higher (less effective) than for localized controls (as described in chapter 3.4).

Table 3.5.1 Classification of 'segregation' and assigned values

Classification	**Description**	**Assigned value**
No segregation	The source is not isolated from the work environment.	1
Partial segregation without ventilation	Sources are partially segregated from the work environment by isolating the source in a separate room (e.g. with open doors and/or windows to the adjacent area). This segregated	0.7

	area is generally not entered by the worker during a given activity or working shift. The air within the separate room is not actively ventilated.	
Partial segregation with ventilation and filtration of recirculated air	Sources are partially segregated from the work environment by isolating the source in a separate room (with open doors and/or windows). This segregated area is generally not entered by the worker during a given activity or working shift. The air within the separate area is actively ventilated and the recirculated air is filtered[a] or there is no air recirculation.	0.3
Complete segregation without ventilation	Sources are completely segregated from the work environment by isolating the source in a fully enclosed and separate room (incl. closed doors & windows). This segregated area is generally not entered by the worker during a given activity or working shift. The air within the separate area is not ventilated.	0.3
Complete segregation with ventilation and filtration of recirculated air	Sources are completely segregated from the work environment by isolating the source in a fully enclosed and separate room (incl. closed doors & windows). The air within the separate area is actively ventilated and the recirculated air is filtered[a] or there is no air recirculation. The segregated area is generally not entered by the worker during a given activity or working shift.	0.1

[a] The filtration of recirculated air needs to be highly efficient in reducing airborne contaminant levels, like HEPA-filters or equivalent.

3.5.4 References

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3.6 Personal enclosure / Separation

3.6.1 Definition

Personal enclosure is defined as providing a worker with a personal enclosure within a work environment, e.g. air-conditioned cabin.

3.6.2 Scientific background

The concept of personal enclosure is similar to that of segregation (see Modifying Factor 'segregation'), except that for personal enclosure not the source but the worker is placed in an enclosure within a work environment. Like for segregation, in case of a personal enclosure the source is always in the far field, because of the dimensions of the personal enclosure and the consequent distance between the source and the breathing zone of the worker. A worker can be separated from several emission sources, and therefore the reduction in exposure due to personal enclosure can apply to multiple far field exposure sources.

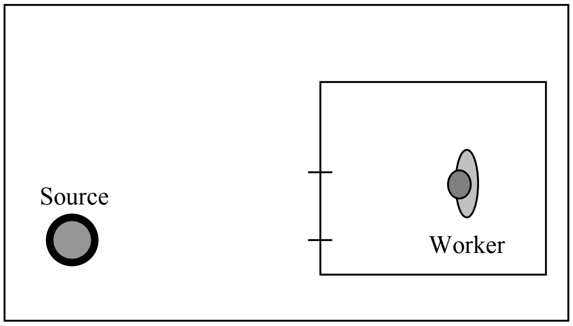

Figure 3.6.1 Complete personal enclosure (doors and windows closed)

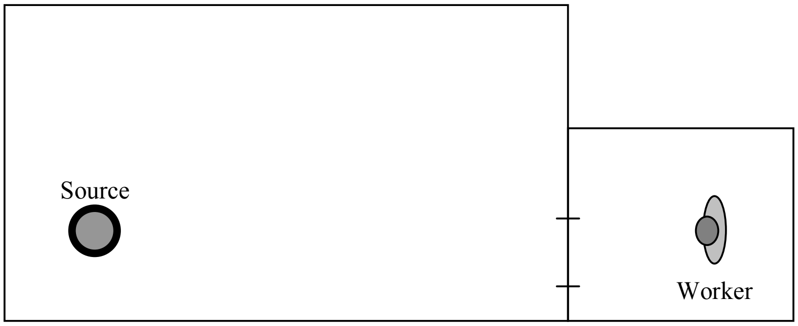

Figure 3.6.2 Complete personal enclosure (doors and windows closed)

Two critical components for an effective enclosed cabin system (or other personal enclosures) are a properly designed, installed and maintained filtration and pressurization system, along with a method for maintaining structural cab integrity (Cecala et al., 2005). For a completely separated cabin, an extract ventilation system can contribute to lower exposure levels especially when the incoming air is filtered (Cecala et al., 2005; Rappaport et al., 2003; Bakke et al., 2002; NIOSH, 2007), but in case of a partial personal enclosure the extract ventilation can actually draw contaminated air into the cabin. Therefore, a major component in an effective system is to ensure that the enclosed cabin is positively air pressured, thereby preventing contaminated air from entering the personal enclosure (Cecala et al., 2005).

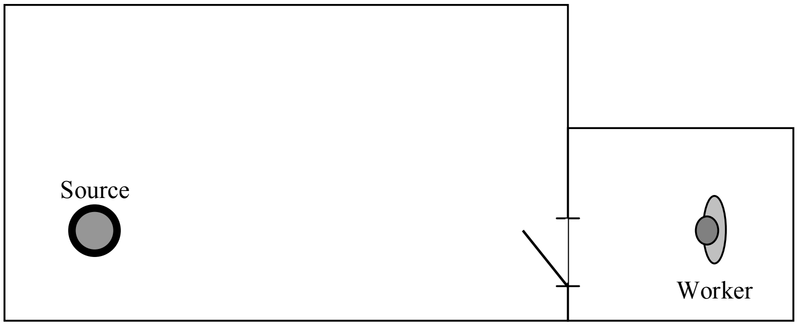

Figure 3.6.3 Partial personal enclosure (doors and/or windows open)

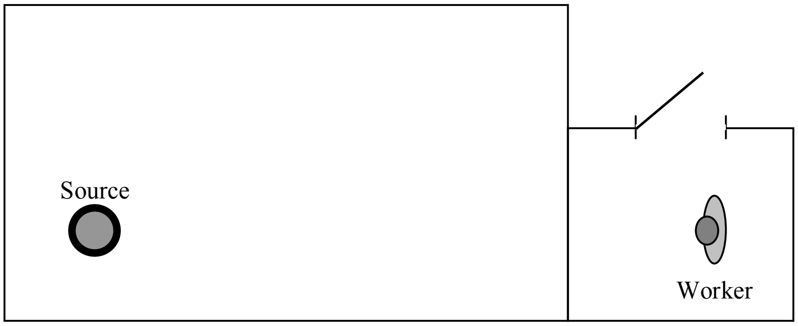

Figure 3.6.4 No personal enclosure (worker is in other department)

The efficacy of a complete personal enclosure with ventilation and effective filtration was estimated to be more than 90% (Cecala et al., 2005), which is supported by the results in the ECEL database (Fransman et al., 2008). The airflow inside the personal enclosure should preferably be top-down, which means that the intake of "clean air" is located in the roof of the separate area (e.g. cabin) and recirculated air is drawn from the bottom of the cabin. This allows the contaminated air to be drawn out of the cabin near the worker's feet and away from the breathing zone. The discharge of clean air low in a cabin wall can entrain significant amounts of dust from soiled work clothes, boots, and a dirty floor (Cecala et al., 2005).

The separated area needs to be in the same department as the source (see Figure 3.6.4), which is in line with the definition of the far field (Tielemans et al., 2008). In a large production facility, there can be a large distance between the separated worker and the source, which will be covered by the modifying factor 'dispersion'. The term 'in the same department' is a rather vague definition and is prone to subjective assessment. This definition should be further refined and described. This issue applies to several modifying factors.

A worker can be completely or partially separated from the source (see Figures 3.6.1, 3.6.2, and 3.6.3). For complete personal enclosure the room or cabin must be closed (doors and windows shut) throughout the entire duration of that activity. Partial personal enclosure is similar to complete personal enclosure, but then with the door or window opened. The opening between the separated room (or cabin) and the area where the source is located should not be larger than a door or a window (see Figure 3.6.5). If the door or window is opened during the activity, the worker is considered to be partially separated throughout the entire duration of the activity. Ott et al. (2003) found that two adjacent rooms with an open door between them with no ventilation system operating behaved as a single compartment. If the worker leaves the separated room or cabin during an activity, the worker is not considered to be separated from the source for that activity. Alternatively, the time outside the personal enclosure could be counted as a different activity.

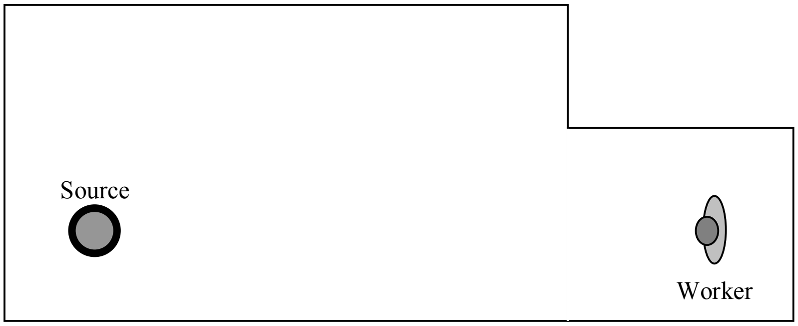

Figure 3.6.5 No personal enclosure (opening between worker and source is larger than a door or window)

3.6.3 Proposal for classification scheme

Any general ventilation inside a separate room is believed to be less effective compared with ventilation inside an enclosure, which is usually tighter around a source (BOHS, 1987). We therefore consider the assigned values for personal enclosure (with ventilation) to be somewhat higher (less effective) than for localized controls (as described in chapter 3.4).

Table 3.6.1 Classification of 'personal enclosure (separation of the worker)' and assigned values

Classification	**Description**	**Assigned value**
No personal enclosure	No personal enclosure within a work environment	1
Partial personal enclosure without ventilation	Partial personal enclosure is a partially open cabin or room (e.g. open windows, door) where a worker is partially protected but still in direct contact with the work environment. The air within the personal enclosure is not actively ventilated.	0.7
Partial personal enclosure with ventilation	Partial personal enclosure is a partially open cabin or room (e.g. open windows, door) where a worker is partially protected but still in direct contact with the work environment. The air within the personal enclosure is ventilated and a positive pressure is maintained inside the personal enclosure.	0.3
Complete personal enclosure without ventilation	Worker resides inside an enclosed cabin or room (door & windows closed) for the entire duration of the activity. The air within the separate room is not actively ventilated.	0.3
Complete personal enclosure with ventilation	Worker resides inside an enclosed cabin or room (door and/or windows closed) for the entire duration of the activity. The air within the personal enclosure is actively ventilated and filtered[a] and a positive pressure is maintained inside the personal enclosure.	0.1

[a] The filtration of air needs to be highly efficient in reducing airborne contaminant levels, like HEPA-filters or equivalent.

3.6.4 References

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Cecala AB, Organiscak JA, Zimmer JA, Heitbrink WA, Moyer ES, Schmitz M, Ahrenholtz E, Coppock CC, Andrews EH (2005). Reducing enclosed cab drill operator’s respirable dust exposure with effective filtration and pressurization techniques. J Occup Environ Hyg; 2:54-63.

NIOSH Technology News No. 528. Recirculating filter is key to improve dust control in enclosed cabs.

Ott WR, Klepeis NE, Switzer P. (2003) Analytical solutions to compartmental indoor air quality models with application to environmental tobacco smoke concentrations measured in a house. J Air & Waste Manage Assoc; 53: 918-936.

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Tielemans E, Schneider T, Goede H, Tischer M, Warren N, Kromhout H, van Tongeren M, van Hemmen J, Cherrie JW (2008). Conceptual model for assessment of inhalation exposure: Defining modifying factors. Ann Occup Hyg; 52(7): 577-586.

3.7 Potential for worker behaviour to affect exposure

3.7.1 Definition

A modifying factor for worker behaviour is intended to take account of the influence on exposure level due to worker movement and possible worker posture very close to the source and other factors causing deviations from the assumption of a completely mixed near-field.

3.7.2 Scientific background

The conceptual model (when ignoring the worker behaviour) assumes that the exposure in the near-field is well-mixed, i.e. there is no variation in the concentration within about 1 m of the worker's nose and mouth. It is clear that this is a considerable simplification of the real situation where exposure may vary over small distances and short timescales. Further, the impact of worker behaviour may be important in particular for near-field sources, where there may be less spatial homogeneity, and to a lesser extent for far-field sources. Small-localised sources will produce greater spatial variation in contaminant air concentration than larger more diffuse sources.

Differences in the behaviour of workers, both within and between individuals, are important in determinants of exposure. However, even if there is considerable spatial variability in the concentration within the near-field, if the behaviour of the worker in relation to the source is a random process then the worker behaviour should not result in any bias of the predicted geometric mean exposure, although this will clearly have an important impact on the exposure distribution and hence on estimates such as the 90th percentile. On the other hand, if the behaviour of workers for a certain exposure scenario (or site) is consistently different from other scenarios (or sites), then their geometric mean exposure will also be systematically different.

Hopkins et al (1986a and b) investigated behavioural controls on workers exposed to styrene. They showed that worker gross behaviour, such as use of ventilation systems, other good work practices and housekeeping measures, could be altered by training and that such changes had the potential to reduce inhalation exposure. Average reduction in exposure varied between about 50% and 85%, although it was not clear exactly which behaviour changes had the biggest effect.

Orientation of the worker to the source may also affect exposure. Lee et al (2007) describe experiments in a small room and showed that workers facing a source had exposures 20% higher than when facing away from the source, and 30% higher for a moving worker compared to a stationary worker (possibly because of increased turbulent mixing of the contaminant in the near-field).

In a scenario the key determinants of the modifying factor for worker behaviour will be the location of the source in relation to the worker and any directed airflows, and the amount of latitude the worker has to interact with the source, for example in terms of restriction of movement near the source because of obstructions or confinement or from defined work methods or protocols.

3.7.3 Proposal for classification scheme

In practical terms, it is often difficult to distinguish between the impact the activity emission potential of the source and the impact that worker behaviour can have on the exposure as these are closely interlinked. Therefore, we believe that the potential impact of worker behaviour on exposure levels will in most cases be sufficiently captured by the Activity Classes, described in Chapter 2.4. Therefore, worker behaviour will not be included in calculating the mechanistic model score.

However, there may still be an additional impact of worker behaviour on the variability in exposure. Another part of the ART model describes how the model will take account of the within- and between-worker variability in exposure.

3.7.4 References

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3.8 Surface contamination and fugitive emission sources

3.8.1 Definition

Emissions from contaminated surfaces arise from the evaporation of liquids or the re-suspension of dusts from leaks, spills or other sources that have produced surface contamination. Fugitive emissions are unintended and unpredictable leaks from process equipment that are not yet classified as a near-field or far-field source. It should be clear that this is different from emission from sources which have been controlled by enclosed control measures which are described in the chapter on localized controls.

3.8.2 Scientific background

Surfaces that may be contaminated include work surfaces, floors, walls, clothing, tools, process equipment, and used rags. Contamination may arise due to leaks or spills, or in the case of particles, deposition from the airborne state. Exposure from these sources will occur through re-suspension of settled dust or evaporation of spilled liquids. These fugitive emission sources may contribute to both near-field and far-field emission levels.

Worker movement and the movement of equipment or vehicles through the workplace will affect exposure from surface contamination sources. Exposure resulting from these sources will be partly dependant on the substance emission potential, with, for example, a dusty substance generally having a higher emission than a less dusty one, and possibly partly on the air concentration of the substance, which may determine the level of surface contamination. In turn the level of contamination will depend on cleaning, housekeeping practices and maintenance practices. Good housekeeping and cleaning practices will generally reduce the opportunity for re-suspension or evaporation from spilled liquids, although certain cleaning activities (for example dry dusting) may in fact result in mechanical disturbance and re-suspension (Thatcher and Layton, 1995). If this is the case, this cleaning should be treated as a separate activity in the ART model.

Schneider (2008) briefly reviews studies of re-suspension of dusts in indoor environments. He notes that smaller particles in direct contact with surfaces are more difficult to re-suspend from surfaces than larger particles and particles $< 1\mu m$ diameter are essentially not re-suspended (although it should be noted that if there is sufficient mass of material settled so that the particles are layered one on another this may not be the case). Also, mechanical disturbance of settled dust greatly increased the rate of emission.

Some authors have proposed that because people are actively re-suspending dusts from their movement and other activities that they are enveloped in a "personal cloud". This "cloud" is actively transporting contaminants into the persons breathing zone because of thermal convection from their body heat. Schneider (2008) notes that contamination on clothing is a major source of particles for the personal cloud. Spills of volatile liquids onto clothing will also contribute to personal exposure.

Fugitive emissions generally arise from liquid or vapours leaking from valves or joints in process equipment. For example, Schroy (1986) lists the vapour emission rates from various pieces of equipment such as flanges and pumps. Much can now be done to reduce fugitive vapour emissions (Onat, 2008). Whilst such emission sources may give rise to relatively large overall emissions from a large plant, such as a petrochemical refinery, it is unlikely that these emissions will have an important impact on occupational exposure. It is also possible that solids being transported in pipes or aerosolised inside process equipment could also give rise to fugitive sources.

It is unlikely that surface contamination or fugitive emissions will be affected by local controls such as ventilation hoods or enclosures since in most cases they will arise from sources not targeted by engineering controls. However, a great deal can be done to reduce fugitive emissions by careful design and maintenance of the process equipment.

3.8.2.1 Existing models

Cherrie *et al.* (1996) defined "passive emission" as the emission of a substance from sources which are not directly associated with the process, for example, the re-suspension of settled dust. They stated that it generally accounted for much less than active emission and originally only three values were specified, corresponding to 1) very poor housekeeping, 2) some sources of passive emission and 3) no passive emission. However, this simple model does not take account of the level of surface contamination or the activity.

In Stoffenmanager (Marquart *et al.*, 2007), background emission covers sources such as leaking machinery, contaminated rags left lying around, spills that haven't been cleaned up, etc. It is assumed that background emission is related to the intrinsic emission, i.e. the modifying factor for background sources was multiplied by the intrinsic emission. Intrinsic emission was then modified by a multiplier determined by how often machines were inspected and on cleaning practices in the work area as shown in the table below. This Table shows the multiplication factors for background sources in Stoffenmanager and shows that for no regular inspection or maintenance, and no daily cleaning the contribution from background sources would be 3% of the intrinsic emission.

Table 3.8.1 Scores for the multiplier for the relative influence of background sources in Stoffenmanager

	No daily cleaning	**Daily cleaning**
No regular inspections and maintenance of machines and equipment	0.03	0.01
Regular inspections and maintenance of machines and equipment	0.01	0

Stoffenmanager aims to avoid the assessor having to make subjective judgments about the level of contamination on workplace surfaces by asking about the frequency of cleaning and inspections and maintenance. However, users of the model may be optimistic concerning the frequency with which these are carried out.

3.8.3 Proposal for classification scheme

It is assumed that the emission from both contaminated surfaces and fugitive sources will generally be small in comparison with the contribution from active emission sources. These fugitive emission sources are assume to be related to housekeeping practices, maintenance of machinery, and the use of protective clothing that repels spills. Fugitive emission sources are assumed to be effectively controlled by processes engineering, at least in so far as they might contribute to occupational exposure, and all sources in the far-field are assumed to be negligible.

The Table below describes the proposed modifying factors for general housekeeping / cleaning / maintenance practices.

Table 3.8.2 Proposed classification for surface contamination

Scenario descriptor	**Modifying factor**
Default level (no specific cleaning practices, no protective clothing that repel spills, process not fully enclosed)	0.01
General good housekeeping practices	0.003
Demonstrable and effective housekeeping practices (examples include daily cleaning using appropriate methods (eg vacuum), preventive maintenance of machinery and control measures, and use of protective clothing that will repel spills and reduce personal cloud)	0.001

Process fully enclosed (air tight) and the integrity of the enclosure is monitored at least once a month. The containment is not breached for example for sampling or routine cleaning.	0

3.8.4 References

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Schneider, T (2008) Dust and fibers as a cause of indoor environment problems. Scand J Work, Env Health; Suppl 4: 10-17.

Schroy JM. A philosophy on engineering controls for workplace protection. Ann Occup Hyg 1986; 30: 231-236.

Thatcher TL, Layton DW (1995) Deposition, resuspension and penetration of particles within a residence. Atmospheric Environment 29: 1487-1497.

3.9 Dispersion

3.9.1 Definition

Dispersion is the movement of a contaminant from a source throughout the work area, giving rise to varying spatial concentrations. The dispersion is dependent on turbulent diffusion and bulk air movement, either because of pressure differences in the room or because of thermal convection. Molecular diffusion is generally an insignificant contribution to the air dispersion of contaminants in workplaces.

This chapter also includes a discussion of the effect of spray rooms/cabins and enclosed spray booths. Spray rooms are enclosed spaced where the general ventilation inlets and outlets are arranged to produce a unidirectional airflow. They do not completely fit into the dispersion approach, although they are clearly not a 'localized control'.

3.9.2 Scientific background

Dispersion from a point source in a large workroom occurs mainly by turbulent diffusion, which can be described relatively simple by using theoretical models. For example, Roach (1981) discusses this problem and shows that the concentration in the room (*C*):

$$C = \frac{m}{4\pi D r} \qquad \text{Equation 3.1}$$

where m is the mass of contaminant released per unit time, D is the diffusion coefficient and r the distance from the source. If m and D are constants then the concentration in the room decreases in inverse proportion to the distance.

In a large room concentration will generally decrease the further the worker is from a source, but clearly in real workplaces dispersion is more complex than the simple model described by Roach (1981). Dispersion through the workspace may not be uniform because the inlet air may not completely mix with the room air, which may be because of poor design of the inlet or exhaust systems or because of the complex geometry within the room.

One approach to attempt to deal with this problem is to use a three-dimensional numerical simulation of the dispersion of an airborne contaminant using a numerical solution of the Navier-Stokes equations using a computational fluid dynamics (CFD) computer programme. For example, Jayaraman et al (2006) describes a CFD study of airborne containments in a ventilated room containing a downdraft table. They investigated the effect of varying the airflows on the effectiveness of the controls and were able to recommend improvements in the system. However, despite the advantages of CFD in investigating specific situations is not practicable as a method of generating a generic approach to dispersion.

A simpler approach to modeling the concentration in indoor spaces that can have wider application was originally suggested by the WC Hemeon (1963), where the room is subdivided into two compartments separated by a virtual boundary through which air can be exchanged. The concentrations in each compartment can be modeled by a simultaneous differential equation. This approach has been remarkably successful in capturing the essence of the contaminant dispersion process.

3.9.3 Indoor dispersion

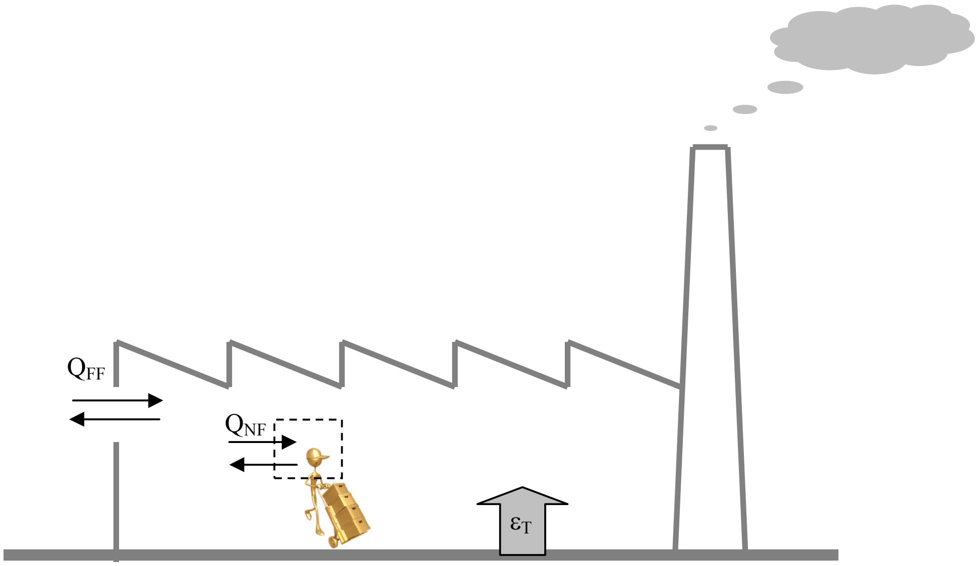
The approach taken in the conceptual model developed for indoor dispersion in the ART project was to divide the workspace into two compartments: the near-field centred on the worker and the far-field comprising the remainder of the indoor space. Simple linked "box models" provide one way to simulate this simple abstraction. For a two-box model, such as for near- and far-field approach, the system is described by two simultaneous first order differential equations representing the exchange of contaminant mass between the compartments, including mass lost from the system. For example, the following equations describe this type of model where the source is located in the near-field:

$$V_{NF}\frac{dC_{NF}}{dt} = \varepsilon_T - C_{NF}.Q_{NF} + C_{FF}.Q_{NF}$$ Equation 3.2

$$V_{FF}\frac{dC_{FF}}{dt} = C_{NF}.Q_{NF} - C_{FF}.Q_{NF} - C_{FF}.Q_{FF}$$ Equation 3.3

Figure 3.9.1 shows a schematic diagram of the model, where the near-field is denoted by the dotted square. The near-field is a virtual 2 m side cube centered on the workers head, with volume V_{NF} = 8 m^3. Q_{FF} is the volume air flow into and out of the far-field and Q_{NF} the volume airflow into and from the near-field. ε_T represents the mass emission rate into the far-field.

Figure 3.9.1 Schematic diagram of the NF-FF model for a source in the far-field



Note, most authors using this approach centre the near-field on the source of the contaminant rather than the worker, and whilst the numerical solutions are similar as when the near-field is centred in the worker we believe that if the main concern is to estimate exposure it is more appropriate to centre the near-field on the person.

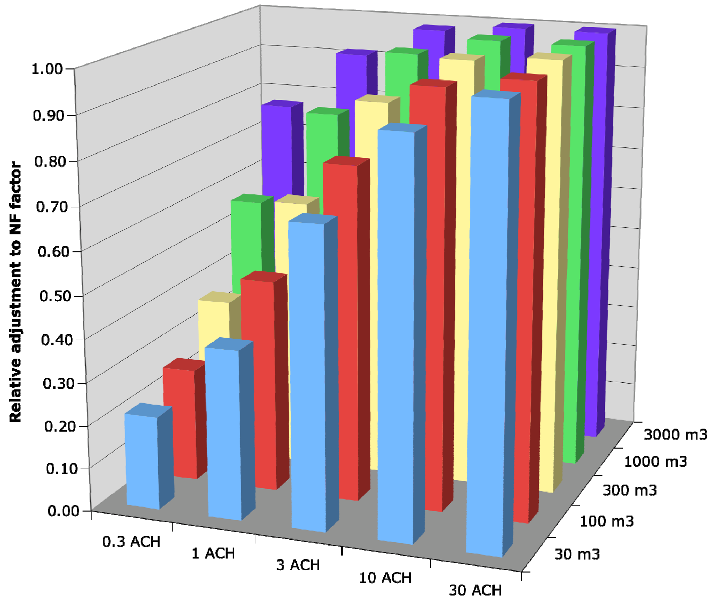
Numerical solution of the simultaneous differential equations provides estimates of the concentration in the near-field, which is assumed to represent the concentration inhaled by the worker. Spencer and Plisko (2007) provide the results from a study to compare this approach to measurements of solvent concentrations while washing metal parts. They identified that the model predictions were generally in good agreement with the model. Similar agreement between model predictions using this approach and measurements has been shown by Nicas et al (2006), Gaffney et al (2008) and Nicas and Neuhaus (2008).

The main limitation in using the box model is the difficulty in defining the emission rate from the source. In most cases it is not possible to *a priori* define what the emission may be, particularly for aerosol emissions. Also, there is generally only limited information available to define the extent of air exchange (air volume flow rate) between the near and far-fields.

Cherrie (1999) investigated the relationship between the air concentration of a contaminant using a two-box model where one box was located around the workers nose and mouth of side 2 m (designated the near-field) and the second box was remainder of the room (designated the far-field). Simulations were run over an 8-hour period. He found that the ratio of the near- to far-field concentration ranged from unity in small poorly ventilated rooms to 24 in large well-ventilated spaces. These data were used to make recommendations about modifying exposure estimates to account for whether sources were located in the near- or far-field that depended on the room size and general ventilation rate.

In this paper we repeated the simulations carried out by Cherrie (1999) but varied the duration of the simulation for 10-minutes, 30-minutes, 1-hr, 4-hr and 8-hr. Following the work of Cherrie (1999) the calculated concentration was normalised to the concentration in the near-field of a 1000 m^3 room with 10 air-changes per hour (ACH). Depending on the duration of the simulation the calculated modifying factors changed, with the biggest changes for small poorly ventilated rooms. This is illustrated in Figure 3.9.2, which shows the ratio of the adjustment factor for a simulated 1-hour task compared to continuous work (8-hr). The factor for the smallest room (30 m^3) at 0.3 ACH for 1-hr work is about a fifth of that calculated for continuous work. For rooms larger than about 300 m^3 and for general ventilation rates at or above 10 ACH the duration of the activity makes little difference.

Figure 3.9.2 Ratio of the adjustment factor at 1-hr to that at 8-hr



3.9.3.2 Continuous vs. intermittent work

In addition to continuous working we also simulated the effect of intermittent work, as might occur in a batch type of process – work lasting 1-hr with a 1-hr gap between each batch. The results from these simulations suggest that for the purposes of the model modifying factor batch work can be considered equivalent to continuous work.

It must be realised that the simulations are an approximation to reality and one should be cautious in not over interpreting the results. For example it would have been useful to have explored more carefully the impact of the mixing of contaminant in the far-field (at the moment it is assumed to occur instantaneously), the size of the near-field, the correlation between airflow rate in the near and far-fields and other factors. Also, the airflow between the near and far-fields may change depending on the presence of a worker close to the source. However, this was not practicable within the current project.

For the modifiers for the ART model it is important to take account of the room size, the general ventilation rate and the duration of the task; modelling of short-term tasks may be required if there is a need to make a comparison of exposure with a short-term Derived No Effect level (DNEL). For simplicity the short-term dispersion modifiers are based on the 1-hr simulations and the long-term modifier on the 8-hr simulations. Values are specified for both near and far-field sources.

3.9.3.3 Impact of particle size on dispersion

In the beta version of the ART mechanistic model the model did not take into account any effect of sedimentation of particles. Further simulations taking into account the additional effect of sedimentation of aerosols on dispersion were carried out for ART version 1.0. The results are included in this chapter as they may impact on some of the exposure scenarios.

The effect of deposition was estimated using results from simulations carried out by Schneider et al (1999). They estimated the deposition velocity to floor, ceilings and walls for various particle sizes (Figure 3 in their paper; copied below).

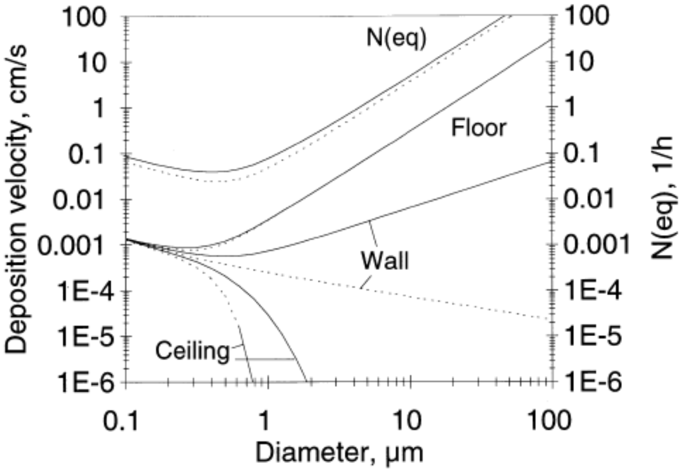


Fig. 3. Deposition velocities on floor, wall and ceiling and the resulting equivalent air exchange rate, $N_{(eq)}$, for $u^* = 0.04$ m s^{-1}. Dashed lines are the result when particle inertia is neglected.

(from Schneider et al., 1999)

Deposition velocities were read from their Figure 3, using a software package. For the near field only the deposition to the floor was taking into account, and the room height was set at 2 m (height of the Near Field box). Next the loss to the floor, walls and ceilings were expressed as equivalent air exchange rates. For the NF this was calculated as:

$$N_{eq,NF} = \frac{V_f}{2}$$

Equation 3.4

$$N_{eq,FF} = \frac{(V_c + V_f)}{H} + \frac{(2 \times V_w \times (L + W))}{(L \times W)}$$

Equation 3.5

The equivalent air exchange rates for the Near Field and Far Field were including in Equations 3.2 and 3.3, respectively:

$$V_{NF}\frac{dC_{NF}}{dt} = \varepsilon_T - C_{NF}.Q_{NF} + C_{FF}.Q_{NF} - \left(N_{eq,NF}.C_{NF}.V_{NF}\right)$$

Equation 3.6

$$V_{FF}\frac{dC_{FF}}{dt} = C_{NF}.Q_{NF} - C_{FF}.Q_{NF} - C_{FF}.Q_{FF} - \left(N_{eq,FF}.C_{FF}.V_{FF}\right)$$

Equation 3.7

Subsequently, simulations were carried out to obtain solutions for these equations. The results of the simulations provide the multipliers for different room sizes and for different monodispersed aerosols. Next, a ‘typical’ particle size distribution was assumed for dusts and mists based on Sabty-Daily et al. (2005). Similarly, for fumes a ‘typical’ particle size distribution was assumed based (Bonnett et al 2000). The tables below with dispersion multipliers provide the final tables with multipliers for dusts/mists and fumes.

3.9.3.4 Indoor dispersion multipliers

The following tables summarise the proposed multipliers for the model by room volume and ACH, for continuous and intermittent work scenarios, stratified by the different exposure forms (vapours/gases, dusts/mists, fumes). Note where a scenario is subdivided into a number of tasks for modelling but the whole scenario represents work over a whole shift then the long-term factors should be used. Because ART will be primarily used to derive full shift exposure estimates, the model uses the long-term multipliers only. The values show the effect of the ventilation and room size on air concentration arising from a process in relation to the concentration that would be measured when the source is in the near-field of the worker who is in a large room with a high level of general ventilation. For example, someone doing a task over a workday with the source in their near-field in a room 30 m^3 with 0.3 ACH would experience a concentration 36 times higher than if they did the same thing in a large well ventilated space (i.e. see Table 3.9.1, Near-Field – top left cell = 36). Similarly if the worker was not actually doing the task but was just in the large well ventilated room, i.e. in the far-field, when the task was carried out then their exposure would be one hundredth of the exposure of the operator doing the task (Table 3.9.2, Far-Field – bottom right cell = 0.01).

Table 3.9.1 Indoor Near-Field Multipliers for vapours (volatile liquids) and gases (long-term; 8-hour tasks)

Room volume (m^3)	**0.3 ACH**	**1 ACH**	**3 ACH**	**10 ACH**	**30 ACH**
30	36	17	7	3	1.6
100	12	6	2.7	1.5	1.1
300	4.8	2.6	1.6	1.1	1.0
1000	2.1	1.5	1.1	1.0	1.0
3000	1.3	1.1	1.0	1.0	1.0

Table 3.9.2 Indoor Far-Field Multipliers for vapours (volatile liquids) and gases (long-term; 8-hour tasks)

Room volume (m^3)	**0.3 ACH**	**1 ACH**	**3 ACH**	**10 ACH**	**30 ACH**
30	35	16	6.1	1.9	0.6
100	12	5	1.8	0.6	0.2
300	3.9	1.6	0.6	0.2	0.1
1000	1.2	0.5	0.2	0.06	0.02
3000	0.4	0.2	0.1	0.02	0.01

Table 3.9.3 Indoor Near-Field Multipliers for dusts, mists (low-volatile liquids), powders in liquids, paste/slurry, solid objects and fibres (long-term; 8-hour tasks)

Room volume (m^3)	0.3 ACH	1 ACH	3 ACH	10 ACH	30 ACH
30	6.3	4.0	2.4	1.4	1.0
100	2.7	1.8	1.3	1.0	0.8
300	1.5	1.1	0.9	0.8	0.8
1000	1.0	0.8	0.8	0.7	0.7
3000	0.8	0.8	0.7	0.7	0.7

Table 3.9.4 Indoor Far-Field Multipliers for dusts, mists (low-volatile liquids), powders in liquids, paste/slurry, solid objects and fibres (long-term; 8-hour tasks)

Room volume (m^3)	0.3 ACH	1 ACH	3 ACH	10 ACH	30 ACH
30	5.7	3.4	1.7	0.8	0.3
100	2.1	1.2	0.6	0.3	0.1
300	0.8	0.4	0.2	0.1	0.04
1000	0.2	0.1	0.1	0.03	0.01
3000	0.1	0.05	0.02	0.01	0.004

Table 3.9.5 Indoor Near-Field Multipliers for fumes (long-term; 8-hour tasks)

Room volume (m^3)	0.3 ACH	1 ACH	3 ACH	10 ACH	30 ACH
30	29.3	14.9	6.5	2.7	1.6
100	10.5	5.3	2.6	1.5	1.1
300	4.3	2.4	1.5	1.1	1.0
1000	2.0	1.4	1.1	1.0	1.0
3000	1.3	1.1	1.0	1.0	0.9

Table 3.9.6 Indoor Far-Field Multipliers for fumes (long-term; 8-hour tasks)

Room volume (m^3)	0.3 ACH	1 ACH	3 ACH	10 ACH	30 ACH
30	28.5	14.0	5.6	1.8	0.6
100	9.6	4.4	1.7	0.5	0.2
300	3.4	1.5	0.6	0.2	0.1
1000	1.0	0.5	0.2	0.1	0.02
3000	0.3	0.2	0.1	0.02	0.01

Note, if these multipliers are used directly in exposure assessments then the next highest value should be selected for a specific situation, e.g. 150 m^3 room with 0.4 ACH should have the multiplier for 100 m^3 and 0.3 ACH selected. However, proposals are made later in this chapter for a more generalized approach for incorporation into the ART model.

Complex shaped rooms provide some further complications to the approach described in this chapter because the assumption about complete mixing throughout the far-field are not appropriate. As a consequence the dispersed concentration in complex shaped rooms may either be higher or lower than would be estimated from the simple analysis depending on the location of sources in the far-field. However, we do not believe that this is a serious limitation in most workplaces. In addition, variations in the orientation of the worker to the source in the near-field and her movement around the source may influence the actual exposure, although probably to a lesser extent than the room and general ventilation parameters – this is discussed further in the chapter on worker behaviour. For example, Lee et al (2007) describe a set of experiments in a small room and demonstrated that workers facing a source had exposures 20% higher than when facing away from the source, and 30% higher for a moving worker compared to a stationary worker (probably because of increased turbulent mixing of the contaminant in the near-field). These issues are discussed more fully in the chapter on worker behaviour.

Care should be exercised in situations where the process involves small localised sources at elevated temperature, e.g. a hot-melt glue gun, or directed emissions from grinding or other similar sources. In these situations the contaminant is released in an air plume and the dispersion is more localised. This causes a particular problem where the user may place her head in the plume. Instructions in the scenario should warn the user against this practice.

We conclude that it is reasonable to use the two-box model approach to provide a generic way of accounting for dispersion from an indoor source. The model identifies that key factors for dispersion are the room size and the general ventilation rate of the room (and different exposure forms (vapours / gases, dusts / mists, fumes)). Although it is clear that in some specialized situations, for example where the workers is located inside a ventilated system (such as for a large paint spray room), this approach does not apply and this is dealt with in the section of this chapter dealing with rooms with unidirectional airflow.

We consider that the approach advocated by Cherrie (1999) should be used in the Advanced REACH Tool. This would require the assessor to define certain aspects of the scenario that would determine the range of general room ventilation, size of the room and scenario duration, and these would then map onto a range of dispersion modifiers. The range of dispersion parameters could then be used in a Monte Carlo simulation to assess both the average dispersion modifier and the range of modifiers reflecting the variation between workplaces. The approach to variability is also discussed more fully in a separate chapter.

Table 3.9.7 sets out the descriptors that should be used for scenarios in relation to dispersion and the associated details of the relevant modifiers. In all cases it should be clear whether the main source is in the near- or far-field and the appropriate values selected from Tables 3.9.1 to 3.9.6. This can be ascertained by the preliminary question: *Is the main source of hazardous substances generally within 1 m of the worker?*

Table 3.9.7 Scenario descriptors for dispersion and associated modifiers: Size of workroom

Scenario descriptor	Modifiers for use in the ART model
Any size workroom	Choose from all relevant cells between 30 and 3000 m^3, with equal probability
Large workrooms only	Choice from relevant cells 300 to 3000 m^3, with equal probability
Small workrooms only	Choice from relevant cells 30 to 100 m^3, with equal probability

Table 3.9.8 Scenario descriptors for dispersion and associated modifiers: Ventilation conditions

Scenario descriptor	Modifiers for use in the ART model
No restriction on general ventilation characteristics	Choose from all relevant cells 0.3 to 3 ACH with equal probability
Only good natural ventilation	Choice from all relevant cells 0.3, 1 and 3 ACH with weighting 20%, 40%, 40%
Mechanical ventilation giving at least 1 ACH	Choice from all relevant cells 1, 3, 10 and 30 ACH with weighting 60%, 30%, 10%
Specialised room ventilation with more than 10 ACH	Choice from all cells 10 to 30 ACH with equal probability

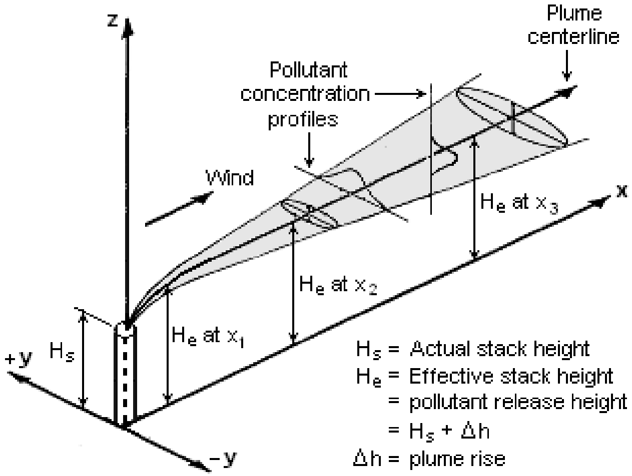
3.9.4 Outdoor dispersion

The dispersion of contaminants outdoors is different from indoors because there are in most cases few boundaries to contain the pollutant in the vicinity of the worker. In addition the strength of the wind will generally be higher than the turbulent airflows inside buildings, typically outdoors the wind speed may be between about 0.5 and 5 m/s whereas indoors it is unusual for wind speed to exceed 0.5 m/s. For these reasons we expect that the dispersion outdoors will be greater than indoors.

The discussion above concentrates on situations where there are no or few boundaries nearby, i.e. the source is not located close to walls or in an enclosed courtyard. Clearly, the assessor needs to make this an explicit assumption in the use of the ART model. The instructions to users should be to use the chemical away from such obstructions. If this is not practicable then the assessor should assume the work is essentially carried out indoors in an appropriately sized room.

We can describe the dispersion of pollutants away from the near-field outdoors by a simple Gaussian dispersion model, as shown in Figure 3.9.3.

Figure 3.9.3 The Gaussian dispersion model



Reproduced from http://en.wikipedia.org/wiki/File:Gaussian_Plume.png

The plume is driven in the longitudinal direction by the wind and in the transverse directions by turbulent diffusion. A simplified expression that describes the downwind concentration C on the plume centre-line for a point source emitted at ground level is:

$$C = \frac{m}{\pi . u . \sigma_y . \sigma_z} \qquad \text{Equation 3.8}$$

where m is the contaminant mass emission rate, u is the wind speed at the source and σ_y and σ_z represents the diffusion constants in the transverse vertical and horizontal directions which describe the increasing spread of the pollutant concentration downwind in the longitudinal direction. These parameters σ_y and σ_z are dependant on distance from the source (i.e. x), as shown in equations 3.5 and 3.6.

$$\sigma_y = a.x^{0.893} \qquad \text{Equation 3.9}$$

$$\sigma_z = c.x^{d} - f \qquad \text{Equation 3.10}$$

where the values a, b, c , d and f are dependant on the atmospheric stability and are determined experimentally and are obtained from published tabulations

Note, in this scheme we are not interested in estimating the dispersion from industrial stacks or building vents, but rather estimating the far-field concentration from outdoor work scenarios.

The concentration in the plume is inversely proportional to the air speed, i.e. doubling the air flow rate decreases the contaminant concentration in the plume to half its original value. In addition, as a first approximation the concentration will decrease in inverse proportion to the distance from the source, i.e. doubling the distance from the source will also half the concentration. However, the more turbulent the air, the more rapidly the plume will spread in the transverse directions. Dispersion of a plume is approximately a cone with angle of about 20^{o}. In most scenarios it will be impossible to say how the worker may be orientated to the wind and so we should assume that there is equal probability that the worker could be orientated at any angle to the wind.

A major limitation of applying this approach is that there is generally no information about the emission strength, which is similar to the situation indoors. In addition, the real pattern of dispersion outdoors will be strongly influenced by surrounding buildings and other obstructions.

We propose to use the same general model for the near-field indoors, i.e. the emission is governed by the substance emission potential, the handing and the efficiency of any local controls. However, for the near-field we choose a higher assumed dispersion rate from the near-field to the far-field to represent the greater dispersion of pollutant. It is assumed there are two situations outdoors where the scenario may be located: close to buildings or away from buildings or other obstructions. If there is no explicit instructions in the scenario other than the work should be undertaken outdoors then it should be assumed that both categories are equally probable.

If it is necessary to calculate the far-field exposure outdoors then the near-field exposure should be adjusted to take account of the distance from the source and the directionality of the dispersion, but not wind speed as this is incorporated in the near-field term. It is assumed there is no preferred direction for dispersion, i.e. the wind direction and the orientation of the worker to the source are essentially random. On a probabilistic basis, average exposure can then be estimated as the fraction of a circle marked out by the dispersion plume, e.g. = 20/360 = 0.056.

It is suggested for work between 1 and 4 m from the source the far-field level should be 0.03 times the near-field concentration and more than 4 m from the source it should be 0.01 times the outdoor near-field level.

We therefore propose the following multipliers for the outdoor scenarios for gasses and vapours:

Table 3.9.9 Outdoor Multipliers for vapours (volatile liquids), gases and fumes

	Close to buildings	**Far from buildings**
NF	1	0.3
FF (1 – 4 m)	0.03	0.01
FF (> 4 m)	0.01	0.003

For dust/mists, we propose to amend the outdoor multipliers, based on the ratio of the results from the indoor simulations for dusts/mists and vapours (indoor, with ACH=10 or 30, room volume = 1000 or 3000). The ratio of the mean multipliers for dusts and vapours were approximately 0.5 for FF and 0.75 for NF, respectively. For fumes these ratios are 0.97 for FF and 0.99 for NF. Therefore, the proposed multipliers for the outdoor scenarios for dusts/mists are:

Table 3.9.10 Outdoor Multipliers for dusts, mists (low-volatile liquids), powders in liquids, paste/slurry, solid objects and fibres

	Close to buildings	**Far from buildings**
NF	0.75	0.2
FF (1 – 4 m)	0.015	0.005
FF (> 4 m)	0.005	0.00167

Because of the negligible difference between the multipliers for vapours and fumes, the same multipliers for fumes can be used as for vapours / gasses (Table 3.9.9).

3.9.5 Unidirectional room airflow

Room enclosures containing the operator and the process may have special ventilation where the air is directed to flow in a single direction. They are frequently referred to as enclosed booths, rooms, or cabins. The main objectives of these enclosures are to 1) contain the contaminant cloud to prevent other employees from being exposed, 2) reduce the process operator’s exposure, 3) discharge cleaned air to the atmosphere. The ventilation inside the room may be: 1) downward (downdraught or vertical airflow), 2) cross-flow (cross-draught or horizontal airflow) or 3) hybrids of these two. The inward and outward airflows should balance to produce a slightly lower pressure than that outside the room (HSE, 2008a).

The clearance time of room enclosures is frequently overlooked. A considerable time may elapse between shutting off the source of hazardous substance and the air in the room being free of significant contamination. The greater the level of turbulent airflow in the room then the longer the clearance time. Good practice requires that:

- the designer should minimize the air clearance time;
- airflow within the room should not stop until the clearance time has elapsed;
- people using unidirectional ventilated rooms should know how to get in and out safely. The room may need an entrance vestibule air-lock;
- the 'ventilation commissioner' needs to establish or confirm the clearance time. The time must be displayed and everyone concerned should be told. (HSE, 2008a)

Workers in unidirectional airflow room enclosures often also need effective respiratory protection. Where necessary, the designer should make provision for respiratory protective equipment (RPE) that needs a clean air supply, for example air plug-in points in the room, near the pedestrian doorway (HSE, 2008a).

3.9.5.1 Downward laminar flow booths

Room enclosures can also be partially enclosed, which are a compromise between containment and accessibility. These so called downward laminar flow booths (or ‘walk-in’ booths) can be very effective, and are defined as a booth, in which a curtain of descending laminar air is created between the ceiling and the rear of the booth where exhaust grilles are located at the lower section (Figure 3.9.4). To be effective in reducing personal exposure levels the worker must not stand at the exhaust grilles and standing in-between the source and the grilles will reduce the effectiveness of the booth. The exhaust volume is typically between 3500-4000 m3/h (per 1m width). Other conditions that make the booth effective are:

- The booths **must** completely enclose the work task and the worker.
- Booth sizes are adaptable to the work task and process equipment and can have varying levels of filtration.
- The filter should have high dust holding capacity, and performance and volume air flow need to be checked regularly.
- For downward laminar flow booths the capture velocity should approximate 0.5 m/second.
- A safe work line (SWL) marks the limit of effective containment and dust capture.

Figure 3.9.4 Downward laminar flow booth

Flow booths can be equipped with partial or full screens with glove ports, potentially offering a further level of containment. These screens can be divided in:

- Partial screens: Partial screens covering the majority of the front of the process/booth; however there may be relatively small openings for operator hands and/or gaps at the top and bottom of the booth.
- Partial screens fitted with glove ports: Partial screen covering the majority of front of process/booth and is fitted with glove ports to allow the operator handle the product; however there may be relatively small gaps at the top and/or bottom of the booth (Figure 3.9.5).
- Full screen fitted with glove ports: Full screen covering the entire front of the process/booth and is fitted with glove ports

Figure 3.9.5 Partial screen fitted with glove ports inside a downward laminar flow booth

3.9.5.2 Spray rooms

Spray rooms are specially designed enclosing rooms (sometimes called 'cabins' or 'booths'), usually including a sophisticated ventilation and control system (HSE, 2008b). The most common design of spray room is the 'downdraft booth'. Air enters the booth through a large area of the ceiling and is extracted through a grated opening in the floor. There are other room designs but they all have the following characteristics:

- they have an air inlet fan and an extract fan;
- the inlet and the outlet air is filtered;
- many have a control panel to program and operate the booth;
- most are manufactured specifically for the motor or commercial vehicle trade. (HSE, 2008b)

Spray rooms are designed to dilute and displace airborne paint mist and reduce the sprayer's exposure. The extract fan removes slightly more air than the inlet fan supplies. This ensures that the room is held at a slightly lower air pressure than the rest of the work area and prevents paint mist leaking out of the room (HSE, 2008b).

It is often mistakenly believed that the air moves smoothly downwards from the ceiling to the floor of the room. In most, if not all, downdraft spray rooms this does not happen. In reality, large, slow-moving vortices are created along all four walls of the room that typically stretch from floor to ceiling. It is in these areas that the fine invisible mist becomes trapped during spraying and for some time afterwards. Unfortunately, the sprayer normally works in these areas (HSE, 2008b), which reduces the effectiveness of spray rooms in practice.

HSE guidance document *Controlling isocyanate exposure in spray booths and spray rooms* (HSE, 2008b) lists the sprayer's seven steps to safe working:

- Remember that most airborne paint mist is invisible.
- All spray booths and rooms have a 'clearance time'. You need to know what it is.
- Always spray paint in a spray booth or spray room and not in the open workshop.
- Always make sure your room runs under negative pressure (so any air leakage is inward).
- Always wear air-fed breathing apparatus during paint spraying.
- Keep your mask on during the clearance time (or leave the booth or room safely).
- Regularly check and maintain your room and air-fed breathing apparatus.

To set the multipliers for spray rooms in comparison with the NF dispersion multipliers in this chapter, we have attempted to compare the effect of unidirectional ventilated rooms with dilution ventilation.

Andersson et al. (1993) described a study in a polyester boat building facility in which horizontal directed ventilation airflow was installed. The study did not compare the styrene exposure before and after installment of this system, which makes it difficult to quantify the impact on exposure. The authors used a grid map technique, that consisted of measuring contaminant concentrations at several locations in the room at (almost) the same time and plotting the concentrations in a (three-dimensional) ‘map’ of the room. They clearly showed that the concentrations of styrene were low 'upwind' of the source and high 'downwind'. Relatively low exposure levels were reached by a combination of the directed airflow towards one side of the room provided the worker positioned himself upstream of the contaminant source, thereby practically segregating the worker from the source. However, this clearly shows that the reliability of the system is entirely dependant on the worker being located in the correct position and if this is not the case then the system will be ineffective.

In a publication of Heitbrink et al. (1995) the effectiveness of different spray rooms was examined. In spray rooms different airflow directions can be used; downdraft (air is blown from the ceiling to the floor), semi-downdraft (air is blown from the wall, and removed at floor level) and cross-draft (air is blown from the wall on one side of the room and removed at the wall on the other side of the room). It was stated that the design of the spray room was mostly based on the process and not on health considerations. During the study, both personal and area total dust samples were taken (on the long side of the spray painting room and near the exhaust filters). The spraying was performed in four downdraft booths, two semi-downdraft booths and two cross-draft booths. Exposure was measured during different activities in the spray painting room, although two different spray guns were used, which complicates the interpretation of the data.

The mean inhalation exposure in the downdraft booths varied from 1.9 - 4.7 mg/m^3. The mean inhalation exposure in the semi-downdraft and cross-draft booths ranged from 7.9 to 9.7 mg/m^3 and 23 to 30 mg/m^3 respectively. The duration of the measurements was not given. It was concluded that the exposure in the downdraft booth was better controlled than in the other booths. In the downdraft booths, both spray guns were used, in the other booths only one type of spray gun was used (in both types of booth, the same spray gun). Since there was a difference in the exposure arising from the two spray guns, and none of the activities performed with the same spray guns were similar, it is difficult to correctly estimate the exposure reduction from each type of booth, although it appears as though a well-designed system can importantly reduce exposure over alternative systems.

There is no definitive information to quantify the reduction in exposure that might be achieved from a unidirectional flow booth compared to the exposure while doing the same task in an open room. Based on the information presented above we propose an additional reduction factor for enclosed spray rooms provided that they are:

- fully enclosed, unidirectional downflow spray room of volume between 30 and 1000 m^3 with at least 10 air changes per hour;
- the spray room has been designed by a competent ventilation engineer, the airflow performance is regularly checked and the ventilation system is maintained;
- the spray room needs to run under negative pressure (i.e. so any air leakage is inward).
- the workers in the spray room must be properly trained in correctly using the room (e.g. operation of the ventilation system, good positioning of the worker relative to the source and the ventilation, knowing the ventilation clearance time of the room).

If these conditions are met then it may be assumed that the NF exposure levels are 0.3 times lower than without using this spray room. Because cross-flow spray rooms are considered to be less effective than down-flow rooms, the cross-flow spray rooms are assigned a similar multiplier as the dispersion NF multiplier.

We assume that there is usually only one (NF) source (i.e. only one worker working at the same time) inside a spray room and therefore no FF multipliers were derived. In the exceptional case that there is more than one worker spraying inside a spray room, we assume that the spray room is effective in reducing the FF source exposure to a minimum.

Table 3.9.11 Unidirectional room air flow multipliers for vapours (volatile liquids), gases and fumes (long-term; 8-hour tasks)

	Assigned value
Spray rooms	
- Cross-flow spray room	1.0
- Down-flow spray room	0.3
Downward laminar flow booth	0.3
- Downward laminar flow booth using partial screen	0.2
- Downward laminar flow booth using partial screen fitted with glove ports	0.15
- Downward laminar flow booth using full screen fitted with glove ports	0.015

Table 3.9.12 Unidirectional room air flow multipliers for dusts, mists (low-volatile liquids), powders in liquids, paste/slurry, solid objects and fibres (long-term; 8-hour tasks)

	Assigned value
Spray rooms	
- Cross-flow spray room	0.7
- Down-flow spray room	0.2
Downward laminar flow booth	0.2
- Downward laminar flow booth using partial screen	0.15
- Downward laminar flow booth using partial screen fitted with glove ports	0.1
- Downward laminar flow booth using full screen fitted with glove ports	0.01

3.9.6 References

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3.10 Respiratory protection

3.10.1 Definition

Respiratory protective equipment (RPE) refers to equipment designed to protect the worker from being exposed to (chemical) substances through inhalation.

3.10.2 Scientific background

The effectiveness of RPE is determined by quantitative comparison of the level of contamination 'outside' and 'inside' the protective device assessed in workplace scenarios for an individual worker who uses RPE (Brouwer et al., 2001). This enables a better assessment of the 'overall' performance of PPE, i.e. 'the proper functioning' of RPE in comparison with the CE-marked laboratory testing of RPE. To determine the Workplace Protection Factor (WPF), field studies have been conducted for various designs of respiratory protective devices (RPD). Outside the respirator and inside the mask concentration of the hazardous chemical are determined to calculate the WPF, where the WPF is the concentration on the outside divided by the concentration on the inside. Most studies have been conducted in the USA according to a protocol drafted by the AIHA (Guy, 1985; Myers *et al*., 1995), but the protocol adopted in the UK is on different principles (BSI, 1997). In WPF-studies according to the AIHA-protocol only workers who are adequately trained and have experience using the respirator design under study, and who have passed a quantitative or qualitative fit test, are included. Prior to the study additional instructions of use are given, and during the study the use of RPD is monitored by investigators. If necessary, additional instructions are given during the study. In the BS 'as is' studies, no additional instructions are given prior to the study and no intervention by investigators is made.
ANSI (ANSI, 1992; Nelson, 1996), and BSI (BSI, 1997) have evaluated all WPF-studies available at a certain point in time, to assign protection factors for various respirator designs in the USA and the UK, respectively. The 'assigned protection factors' (APFs) are 'weighted' 5th-percentiles of the (log-normal) distribution of observed workplace factors, and afforded protection to 95% of adequately trained and instructed wearers, who wear proper functioning and well-fitted respiratory equipment. The Table below summarizes APFs drafted by ANSI and BSI for some types of filtering respirator designs. Partly due to the non-acceptance of 'as is' designed studies for some types of RPD by ANSI, e.g. full face masks, higher APFs have been derived compared to APFs set by BSI. The nominal protection factor (NPF) is shown in the last column, and clearly illustrates the difference between observed workplace protection and test criteria.

Table 3.10.1 Examples of assigned protection factors for filtering devices (Brouwer et al., 2001).

Mask type	Filter type	BS 4275	ANSI Z88.2
Filtering half masks	FFP1	4	-
	FFP2	10	-
	FFP3	20	10
Half or quarter mask	P1	4	-
and filter	P2	10	-
	Gas	10	10
	GasXP3	10	10
	P3	20	10
Filtering half masks	FMP1	4	-
without inhalation	FMP2	10	-
valves	FMGasX	10	10
	FMGasXP3	10	-
	FMP3	20	10

Valved filtering half masks	FFGasXP1	4	-
	FFGasX	10	10
	FFGasXP2	10	-
	FFGasXP3	10	10
Full face masks and filter	P1	4	-
	P2	10	-
	Gas	20	100
	GasXP3	20	-
	P3	40	100
Powered filtering devices incorporating helmets or hoods	TH1 all types	10	100
	TH2 all types	20	100
	TH3 (semi)hood/blouse	40	1000
Power assisted filtering devices incorporating full, half or quarter masks	TM1 (all types)	10	50 (Half-face) / 100 (Half-face)
	TM2 (all types)	20	50 (Half-face) / 100 (Half-face)
	TM3 (half face) particle, gas or combined filters	20	50
	TM 3 (full face) gas or combined filters	40	1000

3.10.3 Proposal for classification scheme

Because the BS APFs reflect the protective effect of RPE derived from workplace surveys according to an 'as is' protocol, this list of protection factors is used to calculate the assigned values for the modifying factor for RPE use. The assigned value for the ART model is recalculated to fit the multiplicative ART model by the inverse of the APFs calculated by BS (BSI, 1997) (assigned value = 1/APF), which means that an APF of 4 equals an assigned value of 0.25 (i.e. a 75% reduction in personal exposure level) (see Table below).

Table 3.10.2 Classification of RPE and assigned values.

Mask type	**Filter type**	**Assigned value**
Filtering half masks	FFP1	0.25
	FFP2	0.10
	FFP3	0.05
Half or quarter mask and filter	P1	0.25
	P2	0.10
	Gas	0.10
	GasXP3	0.10
	P3	0.05
Filtering half masks without inhalation valves	FMP1	0.25
	FMP2	0.10
	FMGasX	0.10
	FMGasXP3	0.10
	FMP3	0.05
Valved filtering half masks	FFGasXP1	0.25
	FFGasX	0.10
	FFGasXP2	0.10
	FFGasXP3	0.10
Full face masks and filter	P1	0.25
	P2	0.10
	Gas	0.05
	GasXP3	0.05
	P3	0.025

Powered filtering devices incorporating helmets or hoods	TH1 all types	0.10
	TH2 all types	0.05
	TH3 (semi)hood/blouse	0.025
Power assisted filtering devices incorporating full, half or quarter masks	TM1 (all types)	0.10
	TM2 (all types)	0.05
	TM3 (half face) particle, gas or combined filters	0.05
	TM 3 (full face) gas or combined filters	0.025

One should realize that these assigned values are a very conservative estimate of the effectiveness of RPE (i.e. the 5th percentile of the distribution of observed workplace protection factors) and that effectiveness of RPE might be more efficient when the device is regularly cleaned and maintained and the worker is properly trained to use the device. For that reason, the effectiveness of RPE is not yet incorporated in the current ART model, but the above Table can be used to estimate the effect of several RPE.

3.10.4 References

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3.11 List of experts for review

The independent experts who reviewed (parts of) the mechanistic model report (in addition to the ART consortium members and Steering Committee members) were:

- R. Alesbury (S. Bailey (GSK, UK)
- D. Brouwer (TNO, The Netherlands)
- M. Byrne (University of Galway, Ireland)
- D. Dahmann (Bochum University, Germany)
- J. Dobbie (BP, UK)
- D. Gazzie (Industrial Health Control, UK)
- A. Gillies (Gillies Associates Ltd, UK)
- E. Joseph (GSK, UK)
- I. Kellie (OHS Scotland Ltd, UK)
- D. Mark (HSL, UK)
- P. McDonnell (University of Galway, Ireland)
- M. Newell (Bayer Crop Sciences, UK)
- M. Nicas (University of California, USA)
- D. O’Malley (Genesis Environmental Ltd, UK)
- M. Piney (HSL, UK)
- A. Robertson (IOM, UK)
- J. Saunders (HSL, UK)
- M. Smith (Bayer Crop Sciences, UK)
- H. Tinnerberg (Lund University, Sweden)
- H. Westberg (Örebro University Hospital, Sweden)
- A. Wolley (Wolley Associates, UK)
- J. Wren (GSK, UK)
- D. Iddon (Lilly, UK)
- R. Battersby (EBRC, Germany)
- D. Vetter (EBRC, Germany)
- C. Smith (SHELL, South Africa)
- J. Urbanus (SHELL)
- D. Noy (DOW Chemicals)

CHAPTER 4

WORKFLOW OF MECHANISTIC MODEL

4 Workflow of mechanistic model

4.1 Introduction

The workflow of the ART mechanistic model is presented in Figure 4.1.1. The first questions are related to the substance. Subsequently, the user should indicate the number of activities that are in the 8-hour scenario (with a maximum of 4 different activities) and duration spent in those activities. Subsequently, questions are asked on the substance emission potential and the user should specify whether the source is located in the near field (NF) or in the far field (FF) of the worker. If there is no emission source in the NF of the worker, then there is only a FF source. Then, questions are asked about 1) the activity emission potential of the FF source, 2) localized controls of the FF source, 3) segregation of the FF source, 4) personal enclosure (separation of the worker), 5) surface contamination, and 6) dispersion (room size and ventilation rate).

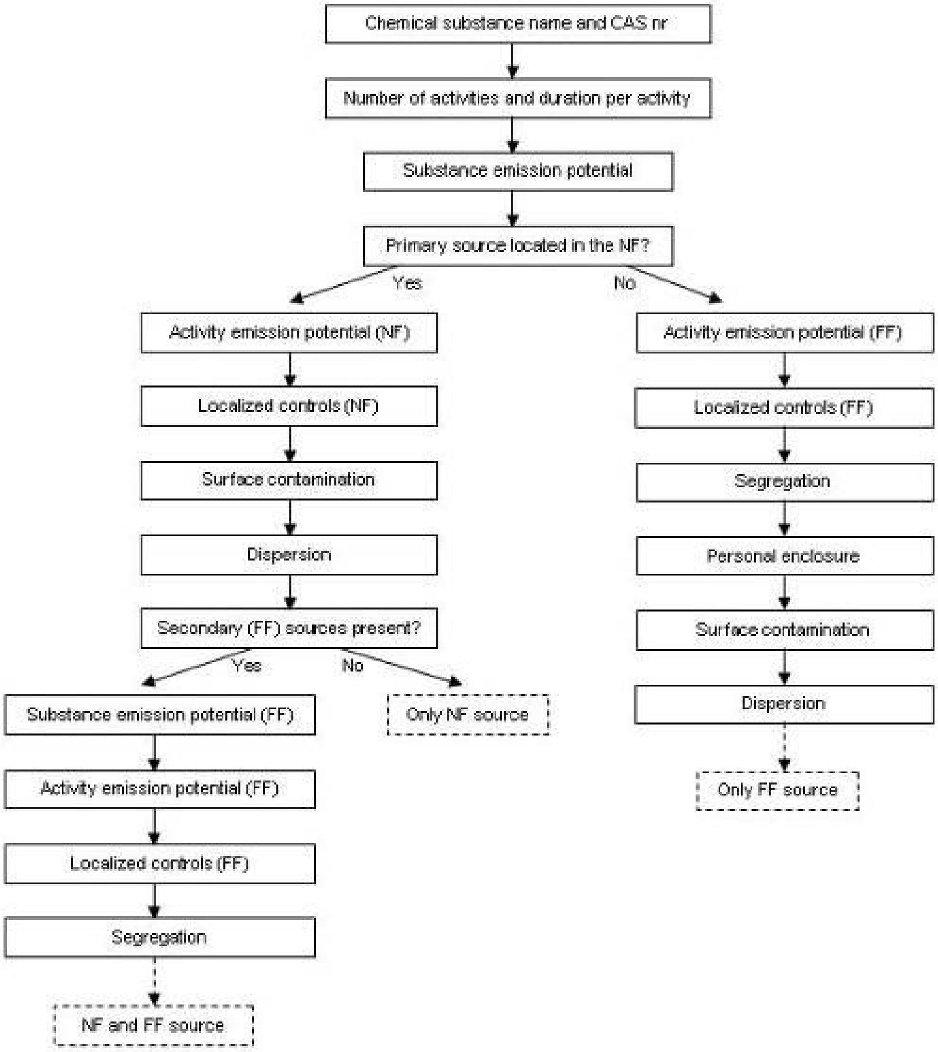


Figure 4.1.1 Workflow of the ART mechanistic model

If there is an emission source located in the NF, then questions are asked about 1) the activity emission potential of the NF source, 2) localized controls (and additional secondary localized controls) of the NF source, 3) surface contamination in the NF, and 4) dispersion (room size and ventilation rate). In addition to questions on the NF source, the user is asked whether a secondary (FF) source is present. If not, then there is only a NF source. If secondary sources are present, then there is a FF source in addition to the NF source and additional questions are asked on 1) substance emission potential of the FF source, 2) activity emission potential of the FF source, 3) localized controls (and additional secondary localized controls) of the FF source, 4) segregation of the FF source and 5) surface contamination in the FF. Although the user can assess the substance emission potential, activity emission potential and localized controls differently for the FF source in comparison with the NF source, these three modifying factors are by default the same for the FF source as for the NF source to reduce the amount of information that the user has to provide.

The entire sequence of questions on modifying factors depicted in Figure 4.1.1 on NF and/or FF sources should be asked for each activity separately (except for the question on chemical substance name (+ CAS nr) and number of activities and duration). We arbitrarily allow a maximum of four different tasks to be assessed within one 8-hour TWA exposure assessment, with a possible addition of a non-exposure period (which will be included as zero exposure).

$$C_t = \left[\frac{1}{t_{total}} \sum_{tasks} \{ t \cdot (C_{nf} + C_{ff} + Su) \} + t_{non-\exp osure} \cdot 0 \right] \cdot RPE$$

Personal exposure due to sources in the NF (C_{nf}) is a multiplicative function of substance emission potential (E), activity emission potential (H), localized control (LC), and dispersion (D). RPE is only considered for the whole composite scenario to allow combination with measurements. Therefore, the use of RPE is asked at the end of the after the Bayesian update for the whole scenario.

$$C_{nf} = (E_{nf} \cdot H_{nf} \cdot LC_{nf1} \cdot LC_{nf2}) \cdot D_{nf}$$

Personal exposure due to sources in the FF (C_{ff}) is a multiplicative function of substance emission potential (E), activity emission potential (H), localized control (LC), segregation (Seg), dispersion (D), and personal enclosure (Sep):

$$C_{ff} = (E_{ff} \cdot H_{ff} \cdot LC_{ff1} \cdot LC_{ff2} \cdot Seg_{ff}) \cdot D_{ff} \cdot Sep$$

Note that there are differences between equations describing exposure related to NF and FF sources. Segregation and personal enclosure (separation of the worker) are not relevant for NF sources. If NF sources and FF sources are both present, then the personal enclosure does not apply, because it is not possible to have a NF source inside your personal enclosure. The factors for substance emission potential, activity emission potential, localized controls, surface contamination, and dispersion can be different for FF sources as compared to NF sources.

Surface contamination is calculated differently for different situations:

1) NF source only (in an activity period)

$$Su = Su_{factor} \cdot (E_{nf} \cdot H_{nf} \cdot LC_{nf1} \cdot LC_{nf2} \cdot D_{nf})$$

2) FF source only

$$Su = Su_{factor} \cdot (E_{ff} \cdot H_{ff} \cdot LC_{ff1} \cdot LC_{ff2} \cdot Seg_{ff} \cdot D_{nf} \cdot Sep_{ff})$$

3) NF & FF sources

$$Su = Su_{factor} \cdot (E_{nf} \cdot H_{nf} \cdot LC_{nf1} \cdot LC_{nf2} \cdot D_{nf})$$

These equations are based on the assumption that the NF and FF compartments are located in the same work area and therefore assume that surface contamination is similar for NF and FF work areas. In addition, it is believed that surface contamination in the NF dominates over the surface contamination in the FF (in case of both NF and FF sources).

All the above equations apply for a situation where operational conditions remain stable. In complex work environments, multiple sources of various source strengths may be present in both the NF and FF. In theory, the contribution of each source should be calculated separately and then added for the NF and FF. In practice, however, it may not be feasible to take into account all sources. The pragmatic solution we chose is to take into account maximally one (main) source in the NF and maximally one (main) source in the FF. It is up to the user to decide which the main source is for the NF and which for the FF.
In case that a person is conducting different consecutive tasks during a time period, each task should be assessed separately and a time-weighted average should be calculated. We allow a maximum of four consecutive activities for one time weighted average exposure assessment.

Remarks:

- Different activities within one 8-hour TWA exposure assessment and different NF and FF sources must be focused on the same (chemical) substance.
- The entire sequence of questions depicted in Figure 4.1.1 on NF and/or FF sources should be asked for each activity separately.
- In total no more than 4 different activities can be included in an 8-hour TWA exposure assessment.
- To reduce the amount of information that the user has to provide, the substance emission potential, activity emission potential and localized controls are by default the same for the FF source in comparison with the NF source. However, if needed the user should be able to assess the substance emission potential, activity emission potential and localized controls differently for the FF source in comparison with the NF source.
- Only a FF source can be segregated, because of the dimensions of the segregated area and the consequent distance between the source and the breathing zone of the worker.
- A personal enclosure (separation of the worker) can only apply if only a FF source exists, because of the dimensions of the personal enclosure and the consequent distance between the source and the breathing zone of the worker. Therefore, the personal enclosure is not present in the questions of the FF source in addition to a NF source (Figure 4.1.1). This leads to the complication that surface contamination in the NF (inside the personal enclosure) cannot be assessed, if only FF questions are asked.
- Room size and ventilation rate to assess dispersion are not asked for the FF source in addition to the NF source (even if the FF source is in a segregated area), because FF sources are defined to be in the same department (same work area) and we believe that the segregated area does not notably contribute to the dimensions of the entire work area.
- FF sources could be 1) machines, 2) co-workers or 3) emanating surfaces.

The classification and assigned values for each of the modifying factors are described in detail in subsequent chapters in line with the ART workflow presented in Figure 4.1.1.

4.2 Substance emission potential

Question 0:
Name and description of the scenario

Answer:
Name <Free text field>
Description <Free text field>

Guidance text:

Appropriate labelling of your scenario will enable you to locate it more easily at a later date.

Question 1:
For which (chemical) substance would you like to perform the exposure assessment?
Answer:
<Free text field>

Guidance text:

The chemical name field is for your information only. The substance can be a single chemical substance, but also broader categories like ‘wood dust’, ‘inhalable dust’ or complex mixtures such as petroleum products.

Question 2:
What is the CAS number of the substance?
Answer:
<Free numeric field>

Guidance text:

The CAS No. field is for your information only. You can verify the CAS number by clicking the link to Chemspider.

Question 2.6:
Select the activities that comprise the scenario.
Answer:
<Free text field> <Duration (min)>
<Free text field> <Duration (min)>
<Free text field> <Duration (min)>
<Free text field> <Duration (min)>
Non-exposure period <Duration (min)>

Question 2.7:
Please specify the duration in minutes of each activity period?
(All periods >0, if sum to less than 480 minutes a warning that this is less than a full work shift should be displayed)

Guidance text:

Your scenario can consist of up to four activities. Assign each activity a name and duration in minutes. The activities together represent one working day and therefore the total duration should be around 480 minutes. ART assessments are still possible if the duration deviates from 480 minutes, but estimates should be treated with some caution as ART variability estimates are based on shift measurements.

If applicable, a non-exposure period can be used and should be assigned a duration in minutes.

Next to each activity name is a tick or cross, indicating whether the activity is ready for use.

Click *Configure Activity* to continue configuring your scenario until each activity has a tick next to it. You will then be able to click the Finish button and run the mechanistic model.

Question 3:
What is the product type of the substance/preparation?
Answer:
Dropdown list with following possibilities:

- Powders, granules or pelletized material
  This category also includes liquids incorporated in granular or pelletized material (e.g. preservative in wood chips) -> *go to question 4*
- Solid objects
  This category also includes liquids incorporated or on the surface of this material (e.g. preservative in timber) -> *go to question 7*
- Liquids -> *go to question 9*
- Powders dissolved in a liquid or incorporated in a liquid matrix (e.g. copper in anti-fouling paint) -> *go to question 15.5.1*
- Paste, slurry or clearly (soaked) wet powder (not containing volatile liquid components) -> go to question 15.1
- Hot or molten metal -> go to question 15.6
- Fibrous material. *[This is outside the applicability domain of the beta version. Should be visible but not selectable.]*
- Gas *[This is outside the applicability domain of the beta version. Should be visible but not selectable.]*

Guidance text:

Select the type of the product at the beginning of the activity.

4.2.1 Powders, granules or pelletized material

Question 4:
What is the measured dustiness of the material (mg/kg for inhalable fraction)?
Answer:
[Numerical value (>0 - 100000)]. *[Based on the answer, one of the dustiness classes in question 5 is selected.]*

Guidance text:

Dustiness of the inhalable fraction may be measured by two methods, the rotating drum test and the continuous single drop test, which is described in detail in CEN EN 15051 (2006). The two test methods do not always rank materials in the same order and users should therefore choose the method that is most appropriate for the material and handling process they wish to simulate.

Question 5:
If the dustiness of the material was not measured: To which dustiness class does the substance belong?
Answer:
Dropdown list with following possibilities:

- Extremely fine and light powder.
- Fine dust.
- Coarse dust.
- Granules, flakes or pellets.
- Firm granules, flakes or pellets.

Descriptions and assigned values of each category are given in the table below:

Classification	**Description**	**Assigned value**	**Indicative dustiness test result (inhalable fraction)**[*]	**Guidance images**
Extremely fine and light powder	A powdered product containing very fine, free flowing, light particles. This category may also contain products with a mixture of very fine particles and large particles or granules. Handling the product in its dry form results in a dust cloud that remains airborne for a long time. The product may be wind swept: e.g., magnesium stearate.	1.0	> 5,000 mg/kg	
Fine dust	A powdered product containing fine particles. This category may also contain products with a mixture of fine particles and large particles or granules. Handling the product in its dry form results in a dust cloud that is clearly visible for some time: e.g., talcum powder, carbon black.	0.3	2,000 – 5,000 mg/kg	
Coarse dust	A powdered product containing coarse particles. Handling the product in its dry form results in a dust cloud that settles quickly due to gravity: e.g. sand.	0.1	501 - 2,000 mg/kg	

Granules, flakes or pellets	Granules or flakes may fall apart and crumble, resulting in only a very limited amount of fine particles. Handling the product does not result in a visible dust cloud; e.g., fertilizer, garden peat, animal pellets.	0.03	101 – 500 mg/kg	
Firm granules, flakes or pellets	Product does not result in dust emission without intentional breakage of products: e.g., firm polymer granules, granules covered with a layer of wax, a woodblock, a brick)	0.01	≤ 100 mg/kg	

Question 6:
What is the moisture content of the product?
Answer:
Dropdown list with following possibilities:

- Dry product (< 5 % moisture content)
- 5 - 10 % moisture content
- > 10% moisture content

Descriptions and assigned values of each category are given in the table below:

Classification	**Assigned value**
Dry product (< 5 % moisture content)	1.0
5 – 10 % moisture content	0.1
> 10 % moisture content	0.01

Guidance text:

Increasing the moisture content or adding other additives can reduce exposure potential. Water may have been added before handling the product or during handling. The latter is taken into account in the principal MF “localized control’, whereas the former is considered an intrinsic property of the material.
Clearly (soaked) wet powdered material (like paste or slurry) should not be treated as a powder and the product type ‘paste or slurry or clearly (soaked) wet powder’ should be selected.

Question 6.5:
What is the weight fraction of the substance in the powdered, granular or pelletized material? If the weight fraction of the substance in the material is not precisely known, pick one of the categories below.
Answer:
<Numeric field (0.0≤weight fraction≤1.0) > or alternatively dropdown list with following possibilities:

- Pure material (100%)
- Main component (50 – 90 %)
- Substantial (10 – 50 %)

- Minor (5 – 10 %)
- Small (1 – 5 %)
- Very small (0.5 – 1 %)
- Extremely small (0.1 – 0.5 %)
- Minute (0.01 – 0.1 %)
- Extremely minute (< 0.01 %)

If one of the above categories is selected, use the median from the table below in calculating the substance emission potential (E).

	Weight fractions		
Weight fraction categories	**Minimum**	**Median**	**Maximum**
Pure material	1	1	1
Main component	0.5	0.7	0.9
Substantial	0.1	0.3	0.5
Minor	0.05	0.075	0.1
Small	0.01	0.03	0.05
Very small	0.005	0.0075	0.01
Extremely small	0.001	0.003	0.005
Minute	0.0001	0.00055	0.001
Extremely minute	0	0.00005	0.0001

E_{solid} = Dustiness * moisture score * (median) weight fraction

[Go to question 16]

4.2.2 Solid objects

Question 7:
What is the weight fraction of the substance in the solid object? If the weight fraction is not precisely known, pick one of the categories below.
Answer:
<Numeric field (0.0≤weight fraction≤1.0)> or alternatively dropdown list with following possibilities:

- Pure material (100%)
- Main component (50 – 90 %)
- Substantial (10 – 50 %)
- Minor (5 – 10 %)
- Small (1 – 5 %)
- Very small (0.5 – 1 %)
- Extremely small (0.1 – 0.5 %)
- Minute (0.01 – 0.1 %)

If one of the above categories is selected, use the median from the table below in calculating the substance emission potential (E).

	Mole or weight fractions		
Mole/weight fraction categories	**Minimum**	**Median**	**Maximum**
Pure liquid	1	1	1
Main component	0.5	0.7	0.9
Substantial	0.1	0.3	0.5

Minor	0.05	0.075	0.1
Small	0.01	0.03	0.05
Very small	0.005	0.0075	0.01
Extremely small	0.001	0.003	0.005
Minute	0.0001	0.0006	0.001

Guidance text:

The fraction of the substance in the solid object should be estimated by expert judgement. For instance, if the quartz content in solid stone is 5%, then 0.05 should be entered here. For impregnated wood logs it will be more difficult to estimate the right proportion of substance in the log.

Question 8:
What is the material of the solid object?
Answer:

- Wood
- Stone (exposure to respirable dust is assessed)
- Metal
- Plastic *[This is outside the applicability domain of the beta version. Should be visible but not selectable]*
- Leather *[This is outside the applicability domain of the beta version. Should be visible but not selectable]*
- Glass *[This is outside the applicability domain of the beta version. Should be visible but not selectable]*
- Textile fabrics *[This is outside the applicability domain of the beta version. Should be visible but not selectable]*
- Other *[This is outside the applicability domain of the beta version. Should be visible but not selectable]*

Question 8.5:
What is the moisture content of the solid object?
Answer:
Dropdown list with following possibilities:

- Dry solid object (< 5 % moisture content)
- 5 – 10 % moisture content
- \> 10 % moisture content

Descriptions and assigned values of each category are given in the table below:

Classification	**Assigned value**
Dry solid object (< 5 % moisture content)	1.0
5 – 10 % moisture content	0.3
> 10 % moisture content	0.03

Guidance text:

Increasing the moisture content or adding other additives can reduce exposure potential. Water may have been added before handling the product or during handling. The latter is taken into account in the principal MF “localized control’, whereas the former is considered an intrinsic property of the material.

Go to question 16

4.2.3 Liquids

Question 9:
What is the temperature of the liquid in the process (in Celsius)? If the process temperature of the liquid is not precisely known, pick one of the categories below.
Answer:
<Numeric field (0≤process temperature≤150) > [If temperature = 15-25 ºC then go to question 10. Else go to question 10.5]
Alternatively dropdown list with following possibilities:

- Hot processes (50 – 150 ºC) -> *go to question 10.5*
- Above room temperature (25 – 50 ºC) -> *go to question 10.5*
- Room temperature (15 – 25 ºC) -> *go to question 10*
- Below room temperature (< 15 ºC) -> *go to question 10.5*

If one of the above categories is selected, use the median process temperature (in Celsius) from the table below in calculating the vapour pressure.

	Temperatures					
	Minimum		**Median**		**Maximum**	
Temperature categories	°C	K	°C	K	°C	K
Hot processes	50	323	75	373	150	423
Above room temperature	25	298	37.5	310.5	50	323
Room temperature	15	288	20	293	25	298
Below room temperature	0	273	7.5	280.5	15	288

Guidance text:

Configure the process temperature then click Next to continue.

Question 10:
What is the vapour pressure (in Pascal) of the substance at room temperature?
Answer:
<Numeric field>

Guidance text:

Enter the vapour pressure (in Pascal) of the pure substance at room temperature (even if it is in a mixture).

Conversion table:

	Pa	**bar**	**atm**	**mmHg**	**Ib in^{-2} (psi)**
Pa	1	$1.00\text{x}10^{-5}$	$1.01\text{x}10^{5}$	$7.50\text{x}10^{-3}$	$1.46 \text{ x } 10^{-4}$
bar	$1.00\text{x}10^{5}$	1	0.987	750	14.5
atm	$1.01\text{x}10^{5}$	1.013	1	760	14.7
mmHg	133	$1.32\text{x}10^{-3}$	$1.31\text{x}10^{-3}$	1	0.019
Ib in^{-2} (psi)	6870	0.068	0.068	51.7	1

[If vapour pressure ≤ 10 then go to question 12*]*
[If vapour pressure > 10 then go to question 14*]*
[If vapour pressure > 100,000 *then warning text: "Substance with a vapour pressure of > 100,000 Pa at room temperature are considered to be gases. The difference between a vapour and a gas is*

that, under ambient environmental conditions, a vapour is present in equilibrium with the volatile liquid. In contrast, for a gas under normal environmental conditions there will be no liquid present. The ART model is not yet suitable for assessing exposure to gases."]

Question 10.5:
If known, what is the vapour pressure (in Pascal) of the substance at this process temperature?
Answer:
<Numeric field [>0]>

Guidance text:

Enter the vapour pressure (in Pascal) of the substance at process temperature (even if it is in a mixture).

Conversion table:

	Pa	**bar**	**atm**	**mmHg**	**Ib in^{-2} (psi)**
Pa	1	1.00x10^{-5}	1.01x10^{5}	7.50x10^{-3}	1.46 x 10^{-4}
bar	1.00x10^{5}	1	0.987	750	14.5
atm	1.01x10^{5}	1.013	1	760	14.7
mmHg	133	1.32x10^{-3}	1.31x10^{-3}	1	0.019
Ib in^{-2} (psi)	6870	0.068	0.068	51.7	1

[If vapour pressure ≤ 10 then go to question 12]
[If vapour pressure > 10 then go to question 14]
[If vapour pressure > 100,000 *then warning text: "Substance with a vapour pressure of > 100,000 Pa at room temperature are considered to be gases. The difference between a vapour and a gas is that, under ambient environmental conditions, a vapour is present in equilibrium with the volatile liquid. In contrast, for a gas under normal environmental conditions there will be no liquid present. The ART model is not yet suitable for assessing exposure to gases."]*

Question 11:
If the vapour pressure at process temperature is not known, what is the boiling point temperature of the substance in the liquid of interest (in Celsius)?
Answer:
<Numerical field [lower limit depending on the process temperature - 2727]>

Guidance text:

Enter the boiling temperature (in degrees Celsius) of the pure substance. In case of complex mixtures provide the lowest boiling point temperature of the mixture.
Both the boiling temperature and the process temperature should be in degrees Celsius. The boiling temperature should be greater than the process temperature.

The vapour pressure at process temperature results from the following equation:

$$\text{Vapour pressure} = 101000 \text{ x } e^{(-10.6 \text{ x } (((\text{boiling temperature (in Celsius)} + 273.15)/(\text{process temperature (in Celsius)} + 273.15))-1))}$$

Both the boiling temperature and the process temperature should be in degrees Celsius. The boiling temperature should be greater than the process temperature.

[If vapour pressure ≤ 10 then go to question 12]
[If vapour pressure > 10 then go to question 14]

[If vapour pressure > 100,000 then warning text: “Substance with a vapour pressure of > 100,000 Pa at room temperature are considered to be gases. The difference between a vapour and a gas is that, under ambient environmental conditions, a vapour is present in equilibrium with the volatile liquid. In contrast, for a gas under normal environmental conditions there will be no liquid present. The ART model is not yet suitable for assessing exposure to gases.”]

4.2.3.1 Low-volatile liquids

Question 12:

[Warning text: The substance is considered low-volatile and exposure to mists is estimated.]
What is the weight fraction of the substance in the liquid mixture? If the weight fraction of the substance in the liquid mixture is not precisely known, pick one of the categories below.

Answer:

<Numeric field (0.0≤weight fraction≤1.0) > or alternatively dropdown list with following possibilities:

- Pure liquid (100%)
- Main component (50 – 90 %)
- Substantial (10 – 50 %)
- Minor (5 – 10 %)
- Small (1 – 5 %)
- Very small (0.5 – 1 %)
- Extremely small (0.1 – 0.5 %)
- Minute (0.01 – 0.1 %)

If one of the above categories is selected, use the median from the table below in calculating the substance emission potential (E).

	Mole or weight fractions		
Mole/weight fraction categories	**Minimum**	**Median**	**Maximum**
Pure liquid	1	1	1
Main component	0.5	0.7	0.9
Substantial	0.1	0.3	0.5
Minor	0.05	0.075	0.1
Small	0.01	0.03	0.05
Very small	0.005	0.0075	0.01
Extremely small	0.001	0.003	0.005
Minute	0.0001	0.0006	0.001

Question 13:

What is the viscosity of the substance/preparation?

Answer:

Dropdown list with following possibilities:

- Liquids with low viscosity (like water)
- Liquids with medium viscosity (like oil)

Descriptions and assigned values of each category are given in the table below:

Classification	**Assigned value**
Liquids with low viscosity (like water)	1.0

Liquids with medium viscosity (like oil)	0.3

The substance emission potential of low-volatile substance i (E_i) is calculated by using:
*E_i = (10/30000) * (median) mol fraction * viscosity.*

Go to question 16

4.2.3.2 Volatile liquids

Question 14:

[Warning text: The substance is considered volatile and exposure to vapors is estimated.]
What is the mole fraction of the substance in the liquid mixture? If the mole fraction is unknown, assume that this is the same as the weight fraction. If the weight fraction of the substance in the liquid mixture is not precisely known, pick one of the categories below.
Answer:
<Numeric field (0.0≤mole fraction≤1.0)> or alternatively dropdown list with following possibilities:

- Pure liquid (100%)
- Main component (50 – 90 %)
- Substantial (10 – 50 %)
- Minor (5 – 10 %)
- Small (1 – 5 %)
- Very small (0.5 – 1 %)
- Extremely small (0.1 – 0.5 %)
- Minute (0.01 – 0.1 %)

If one of the above categories is selected, use the median from the table below in calculating the substance emission potential (E).

	Mole or weight fractions		
Mole/weight fraction categories	**Minimum**	**Median**	**Maximum**
Pure liquid	1	1	1
Main component	0.5	0.7	0.9
Substantial	0.1	0.3	0.5
Minor	0.05	0.075	0.1
Small	0.01	0.03	0.05
Very small	0.005	0.0075	0.01
Extremely small	0.001	0.003	0.005
Minute	0.0001	0.0006	0.001

Question 15:
If known, please provide the activity coefficient for the substance in this mixture?
(One method for estimating activity coefficient for liquid mixtures is using the UNIFAC method, which can be found at http://www.pvv.org/~randhol/xlunifac/). The default value is set at 1.

Answer:
<Numerical field [0.001-1000]>
[Default value = 1]

The table below provide some guidance for choosing the activity coefficient.

Product	Activity coefficient
Pure liquid	1
Liquid solutions	XLUNIFAC (or similar)
Similar organic solvents	1-4
Insoluble solids	1 (for solids)
Sparingly soluble liquids	$\frac{1}{\text{maximium solubility}}$

Guidance text:

When estimating the vapour pressure for substances in a mixture one needs to account for the fact that more than one substance will contribute to the overall vapour pressure. This is based on a fundamental thermodynamic relationship called Raoult's law. Raoult's law relates the vapour pressure of the components to their composition in an ideal solution. A correction factor is introduced into Raoult's law so it can be used to find the vapour pressures above non-ideal solutions. This correction factor is called the activity coefficient, γ. It describes how interactions between the components' molecules in solution affect composition (expressed as mole fraction, x_i) and hence the vapour pressure exerted by the components of the mixture. Activity coefficients can be determined experimentally. In addition a computer software tool called UNIFAC is available to estimate the activity coefficients, which can be found at http://www.pvv.org/~randhol/xlunifac/.

The partial vapour pressure of a substance in a mixture $p_{i,mix}$ is obtained from the following equation:

$$p_{i,mix} = \gamma_i \chi_i p_i \quad \text{(Equation 4.7)}$$

Where,

γ_i = the activity coefficient of substance i

χ_i = the mol fraction of substance i

p_i = the vapour pressure of the substance at the given temperature

The substance emission potential of volatile substance i (E_i) is calculated by using:

$E_i = p_{i,\ mix} / 30000$ (with $E_i = 1$ if $p_{i,\ mix} > 30000$ Pascal)

4.2.4 Paste, slurry or clearly (soaked) wet powder

Question 15.1:

Is the paste or slurry (potentially) contaminated with powdered material?

Answers:

- Yes -> go to question 15.2
- No -> Warning text if this option is selected: "There is no potential for exposure through inhalation from this source." -> STOP. No further questions.

Question 15.2:

What is the measured dustiness of the powder contamination on the paste or slurry (mg/kg for inhalable fraction)?

Answer:

[Numerical value (0-100000)]. *[Based on the answer, one of the dustiness classes in question 15.3 is selected.]*

Guidance text:

Dustiness may be measured by two methods, the rotating drum test and the continuous single drop test, which is described in detail in CEN EN 15051 (2006). The two test methods do not always rank materials in the same order and users should therefore choose the method that is most appropriate for the material and handling process they wish to simulate.

Question 15.3:
If the dustiness of the powder was not measured: To which dustiness class does the substance belong?
Answer:
Dropdown list with following possibilities:

- Extremely fine and light powder.
- Fine dust.
- Coarse dust.
- Granules, flakes or pellets.
- Firm granules, flakes or pellets.

Descriptions and assigned values of each category are given in the table below:

Classification	**Description**	**Assigned value**	**Indicative dustiness test result (inhalable fraction)***	**Indicative dustiness test result (respirable fraction)***	**Guidance images**
Extremely fine and light powder	A powdered product containing very fine, free flowing, light particles. This category may also contain products with a mixture of very fine particles and large particles or granules. Handling the product in its dry form results in a dust cloud that remains airborne for a long time. The product may be wind swept: e.g., magnesium stearate.	1.0	> 5,000 mg/kg	≥ 500 mg/kg	
Fine dust	A powdered product containing fine particles. This category may also contain products with a mixture of fine particles and large particles or granules. Handling the product in its dry form results in a dust cloud that is clearly visible for some time: e.g., talcum powder, carbon black.	0.3	2,000 – 5,000 mg/kg	150 mg/kg	
Coarse dust	A powdered product containing coarse particles. Handling the product in its dry form results in a dust cloud that settles quickly due to gravity: e.g. sand.	0.1	501 - 2,000 mg/kg	50 mg/kg	

Granules, flakes or pellets	Granules or flakes may fall apart and crumble, resulting in only a very limited amount of fine particles. Handling the product does not result in a visible dust cloud; e.g., fertilizer, garden peat, animal pellets.	0.03	101 – 500 mg/kg	15 mg/kg	
Firm granules, flakes or pellets	Product does not result in dust emission without intentional breakage of products: e.g., firm polymer granules, granules covered with a layer of wax, a woodblock, a brick)	0.01	≤ 100 mg/kg	≤ 5 mg/kg	

Question 15.4:
What is the weight fraction of the substance in the powdered contamination on the paste or slurry? If the weight fraction of the substance in the material is not precisely known, pick one of the categories below.
Answer:
<Numeric field> or alternatively dropdown list with following possibilities:

- Pure material (100%)
- Main component (50 – 90 %)
- Substantial (10 – 50 %)
- Minor (5 – 10 %)
- Small (1 – 5 %)
- Very small (0.5 – 1 %)
- Extremely small (0.1 – 0.5 %)
- Minute (0.01 – 0.1 %)
- Extremely minute (< 0.01 %)

If one of the above categories is selected, use the median from the table below in calculating the substance emission potential (E).

		Weight fractions	
Weight fraction categories	**Minimum**	**Median**	**Maximum**
Pure material	1	1	1
Main component	0.5	0.7	0.9
Substantial	0.1	0.3	0.5
Minor	0.05	0.075	0.1
Small	0.01	0.03	0.05
Very small	0.005	0.0075	0.01
Extremely small	0.001	0.003	0.005
Minute	0.0001	0.00055	0.001
Extremely minute	0	0.00005	0.0001

E_{paste} = Dustiness * (median) weight fraction

4.2.5 Powders dissolved in a liquid or incorporated in a liquid matrix

Question 15.5.1:

What is the weight fraction of the powdered substance in the liquid mixture? If the weight fraction of the substance in the liquid mixture is not precisely known, pick one of the categories below.

Answer:

<Numeric field (0.0≤weight fraction≤1.0) > or alternatively dropdown list with following possibilities:

- Main component (50 – 90 %)
- Substantial (10 – 50 %)
- Minor (5 – 10 %)
- Small (1 – 5 %)
- Very small (0.5 – 1 %)
- Extremely small (0.1 – 0.5 %)
- Minute (0.01 – 0.1 %)

If one of the above categories is selected, use the median from the table below in calculating the substance emission potential (E).

	Mole or weight fractions		
Mole/weight fraction categories	**Minimum**	**Median**	**Maximum**
Main component	0.5	0.7	0.9
Substantial	0.1	0.3	0.5
Minor	0.05	0.075	0.1
Small	0.01	0.03	0.05
Very small	0.005	0.0075	0.01
Extremely small	0.001	0.003	0.005
Minute	0.0001	0.0006	0.001

Question 15.5.2:

What is the viscosity of the powder/liquid mixture?

Answer:

Dropdown list with following possibilities:

- Liquids with low viscosity (like water)
- Liquids with medium viscosity (like oil)

Descriptions and assigned values of each category are given in the table below:

Classification	**Assigned value**
Liquids with low viscosity (like water)	1.0
Liquids with medium viscosity (like oil)	0.3

The substance emission potential of powder i dissolved in liquid (E_i) is calculated by using:
*E_i = (10/30000) * (median) mol fraction * viscosity.*

Go to question 16

4.2.6 Hot or molten metal

Question 15.6:
What is the weight fraction of the metal of interest in the molten metal mixture? If the weight fraction of the metal of interest in the molten metal mixture is not precisely known, pick one of the categories below.
Answer:
<Numeric field (0.0≤weight fraction≤1.0) > or alternatively dropdown list with following possibilities:

- Pure material (100%)
- Main component (50 – 90 %)
- Substantial (10 – 50 %)
- Minor (5 – 10 %)
- Small (1 – 5 %)
- Very small (< 1 %)

If one of the above categories is selected, use the median from the table below in calculating the substance emission potential (E).

	Mole or weight fractions		
Mole/weight fraction categories	**Minimum**	**Median**	**Maximum**
Pure material	1	1	1
Main component	0.5	0.7	0.9
Substantial	0.1	0.3	0.5
Minor	0.05	0.075	0.1
Small	0.01	0.03	0.05
Very small	0	0.005	0.01

Question 15.7:
What is the process temperature of the molten metal mixture (in Celsius)?
Answer:
<Numeric field>

Question 15.8:
What is the melting point temperature of the metal of interest (in Celsius)?
Answer:
<Numeric field>

The weighting of the temperature of the molten metal mixture in relation to the melting point of the metal of interest is derived from the table below:

Tmixture/MPt metal of interest	**Examples**	**Weighting**
> 2.5	$T_{mixture} = 1600\ ^oC$ MPt metal A = 600 ^oC	3
1.5 - 2.5	$T_{mixture} = 1000\ ^oC$ MPt metal A = 500 ^oC	2
< 1.5	$T_{mixture} = 625\ ^oC$ MPt metal A = 500 ^oC	1

The substance emission potential of molten metal i in molten metal mixture (E_i) is calculated by using:
*E_i = (median) weight fraction * temperature weighting*

4.3 Near and/or far field sources

Question 16:
Is the primary emission source located in the breathing zone of the worker (i.e. the volume of air within 1 meter in any direction of the worker's head)?
Answer:
Dropdown list with following possibilities:

- Yes -> *go to question 55*
- No -> *go to question 17*

Guidance text:

The approach taken in the ART conceptual model was to divide the workspace into two compartments: the near-field centred on the worker (i.e. the volume of air within 1 meter in any direction of the worker's head) and the far-field comprising the remainder of the indoor space.
Total personal exposure is the sum of emission contributions from near-field and far-field sources.
If you answer yes to this question, the assessment for this activity will involve a primary near-field emission source and an optional secondary far-field source.
If you answer no to this question, the assessment for this activity will involve a primary far-field emission source only.

4.4 Activity emission potential (FF source)

Question 17:
To which activity class does your activity belong?
Answer:
Dropdown list with following possibilities:

[Based on the product type selected in question 3, the activity classes marked with a '+' in the table below should appear in the dropdown list.]

Activity class	**Description [given by mouse-over]**	**Applies for "solid objects"**	**Applies for Powdered, granular and pelletized material**	**Applies for liquids and powders dissolved in a liquid**	**Applies for paste, slurry or clearly wet powder**	**Applies for hot or molten metals**
Fracturing and abrasion of solid objects	Activities where solid objects are broken into smaller parts or are abraded due to frictional forces.	+	-	-	-	-
Abrasive blasting	A surface preparation technique for removing coatings or contamination by propelling abrasive material towards the surface at high velocity. ART only considers exposure arising from the surface coatings during abrasive blasting (i.e., exposure to the abrasive material is not included)	+	-	-	-	-
Impaction on contaminated solid objects	Activities where impaction or striking of a tool on an object contaminated with powder or granules potentially results in re-suspension of that powder. For this activity	-	+	-	-	-

	class, exposure is estimated to be related to the level of contamination on the surface or the object that is impacted on.					
Handling of contaminated solid objects or paste	Handling or transport of surfaces, objects or pastes that are (potentially) contaminated with powders or granules. For this activity class, exposure is estimated to the contamination on the surface, object or paste.	-	+	-	+	-
Spray application of powders	Spraying activities used to intentionally disperse powders on surfaces by using a pressure difference.	-	+	-	-	-
Movement and agitation of powders, granules or pelletized material	Activities where movement and agitation of powders results in disturbances of the product causing dust particles to become airborne.	-	+	-	-	-
Transfer of powders, granules or pelletized material	Activities where a stream of powder is transferred from one reservoir (or container, vessel) to the receiving vessel. The product may either fall due to gravity from a high to a lower point (dumping of powders), be transferred horizontally (scooping of powders) or is transferred through a hose or tube with pressure (vacuum transfer).	-	+	-	-	-
Compressing of powders, granules or pelletized material	Activities where powders, granules or pelletized material are compressed due to compaction or crushing.	-	+	-	-	-
Fracturing of powders, granules or pelletized material	Activities where powders, granules or pelletized material are crushed and broken into smaller parts or sizes due to frictional forces (e.g. between two surfaces or objects)	-	+	-	-	-
Spray application of liquids	Activities used to atomise liquids into droplets for dispersion on surfaces (surface spraying) or into air (space spraying). Spraying techniques may be used for dispersion of e.g. pesticides, biocides, and paints.	-	-	+	-	-
Activities with open liquid surfaces or open reservoirs	Handling of a liquid product in a bath or other reservoir. The liquid may either be relatively undisturbed (e.g. manual stirring, dipping in bath) or agitated (e.g. gas bubbling, mechanical mixing in vessel).	-	-	+	-	-
Handling of contaminated objects	Handling of solid objects that are treated or contaminated with the liquid of interest.	-	-	+	-	-

Spreading of liquid products	Activities where a liquid product is directly spread on surfaces using e.g. a roller, brush or wipe.	-	-	+	-	-
Application of liquids in high speed processes	High energy activities with e.g. rotating tools where liquids are added to the process (e.g. metal working fluids).	-	-	+	-	-
Transfer of liquid products	Activities where a stream of liquid product is transferred from one reservoir to the next. The stream may either fall or glide from high to a lower point (falling liquids) or is transferred with pressure (pressurized transfer: e.g. bottom loading).	-	-	+	-	
Burning of liquids [*This is outside the applicability domain of the beta version. Should be visible but not selectable]*		-	-	+	-	-
Smelting and melting of metal		-	-	-	-	+
Pouring or tapping of molten metal (including melt drossing and dipping in molten metal)		-	-	-	-	+
Sintering, roasting and oxidation / burning		-	-	-	-	+
Spray application of molten metal		-	-	-	-	+
Atomisation		-	-	-	-	+
Compressing of, impaction on, or hardening of hot metal objects		-	-	-	-	+

See table below for combination of activity classes and subclasses with example activities. Show the example activities with the dropdown lists above (mouse-over function).

Activity class	**Activity subclass**	**Example activities**
Fracturing and abrasion of solid objects		• Crushing concrete • Jack hammering • Pulverizing • Sawing using a circular saw • (Manual) milling • Sanding • (Cut-off) grinding of steel • Drilling • Buffing • Polishing • Chiselling • Cutting • Logging • Demolishing with wrecking ball • Wrecking • Shredding of batteries • Wire drawing • Cold rolling of metal sheets
Abrasive blasting		• Grit blasting • (Ultra) high pressure blasting for stripping paint • Water cutting
Impaction on contaminated solid objects		• Hammering • Nailing

		• Piling • Punching
Handling of contaminated solid objects or paste		• Sorting • Stacking • Carrying • Picking / collecting objects • Packaging • Paving • Wrapping • Disposal of empty bags • Plastering • Kneading • Modelling of product • Bending metal tubes
Spray application of powders		• Dusting crops • Powder coating • Spraying of concrete
Movement and agitation of powders, granules or pelletized material		• Sweeping • Application of compressed air • Vacuum cleaning • Mixing • Weighing • Raking • Sieving
Transfer of powders, granules or pelletized material	Falling of powders, granules or pelletized material	• Bagging solids • Dumping solids in mixers • Loading barges with minerals or cereals • Scooping • Scattering • Filling of bottles
	Vacuum transfer of powders, granules or pelletized material	• *[picture vacuum transfer]*
Compressing of powders, granules or pelletized material		• (steam)Rolling • Compacting • Tabletting • Granulation • Pelletization
Fracturing of powders, granules or pelletized material		• Grinding minerals • Milling cereals • Very small scale crushing • Testing tablets • De-lumping (breaking up products) • Large scale bulk milling
Spray application of liquids	Surface spraying of liquids	• Spray application of paints on e.g. ships (using HVLP or airless techniques) • Pest control operations (using backpack) • Spraying cleaning agents onto surfaces • Foaming • Tractor mounted spraying
	Spraying of liquids in a space	• Spraying room deodorizers or fragrances • Fogging • Fly spray
Activities with open liquid surfaces or open reservoirs	Activities with relatively undisturbed surfaces (no aerosol formation)	• Dipping objects in a cleaning bath (where the presence of treated surfaces in the area is limited) • Immersion of objects • Manual stirring of paint • Tank dipping
	Activities with agitated surfaces	• Electroplating • Bath with gas bubbling • Mechanical mixing / blending of paint • Aeration of waste water • Boiling • Shaking liquids (e.g. in chemical laboratories)
Handling of contaminated objects		• Heat drying tasks • Evaporation from painted surface or object • Maintenance of fuel pumps • Coupling and decoupling of hoses or (drilling) equipment

		• Handling of contaminated tools
Spreading of liquid products		• Painting a ceiling and walls with a roller and a brush • Hand lay-up activities with styrene • Pouring a liquid flooring material on a floor • Cleaning of liquid spills • Gluing • Mopping • Embalming • Laminating • Lubricating • Sponging • Screen printing • Cleaning of oil residue from bulk tanks
Application of liquids in high speed processes (e.g. rotating tools)		• Use of metal working fluids with e.g. circular saws and drills • Centrifuging wet items • Press printing
Transfer of liquid products	Bottom loading	• Bottom loading of tanker at bulk terminal • Under wing refuelling of aircraft • Transfer of additives in tanker using bottom loading
	Falling liquids	• Top loading of tanker at bulk terminal (boats, rail car or truck) • Filling of drums • Pouring • Filling of bottles • Filling of paint gun • Refuelling of cars • Manual calibration of fuel pump • Over wing refuelling of aircraft
Smelting and melting of metal	Smelting of metal	•
	Melting of metal	•
Pouring or tapping of molten metal (including melt drossing and dipping in molten metal)	Pouring or tapping of molten metal	•
	Dipping in molten metal	•
Sintering, roasting and oxidation / burning	Sintering	•
	Roasting	•
	Oxidation or burning	•
Spray application of molten metal		•
Atomisation		•
Compressing of, impaction on, or hardening of hot metal objects		• Quenching • Hot rolling • Metal cladding • Hot forging

Guidance text:

Use the left-hand panel to select the activity class that best fits this emission source.
In some cases an activity class has several subclasses. Use the drop-down list in the right-hand panel to narrow down your selection.
For each activity class/subclass you will be shown several activities typical for the selected class.

In the next paragraphs, each of the activity (sub)classes is further defined. Based on the choice in the dropdown list above go to the relevant section below.

4.4.1 Fracturing and abrasion of solid objects

Question 18:
Which of the situations below does best represent your activity?
Answer:

Dropdown list with following possibilities:

Wood:

- Mechanical sanding of wood resulting in large amounts of dust
- Mechanical handling of wood resulting in large amounts of dust (e.g., large speed of moving work pieces or rotating cutting blades)
- Mechanical handling of wood resulting in limited amount of dust
- Manual handling of wood resulting in limited amount of dust
- Manual handling of wood resulting in very limited amount of dust

Stone

- Mechanical pulverization of large amounts of stone or large objects
- Mechanical treatment / abrasion of large surfaces
- Mechanical treatment / abrasion of small sized surfaces
- Mechanical pulverization of stones
- Manual pulverization or treatment / abrasion of small sized objects
- Careful breaking stones

Metal

- Mechanical abrasion or fracturing of metal resulting in small amount of dust
- Mechanical abrasion or fracturing of metal resulting in very limited amount of dust
- Mechanical deforming of metal

Classes and related exposure weights representing emission potential for fracturing and abrasion of **wood**.

Description	**Examples**	**Exposure weights**
Mechanical sanding of wood resulting in large amounts of dust	belt sanding, handheld sanding machine	30
Mechanical handling of wood resulting in large amounts of dust (e.g., large speed of moving work pieces or rotating cutting blades)	milling operations, lathe, circular saw	10
Mechanical handling of wood resulting in limited amount of dust	planer, chainsaw, shredder, drilling of holes	3
Manual handling of wood resulting in limited amount of dust	manual sawing or sanding, scraping of paint	3
Manual handling of wood resulting in very limited amount of dust	screw setting, manual planing	0.3

Classes and related exposure weights representing emission potential for fracturing and abrasion of stone.

Description	**Examples**	**Exposure weights**
Mechanical pulverization of large amounts of stone or large objects	Stone crushing machines, demolition using explosives, using a jack hammer to demolish large surfaces, demolition using a crane	100
Mechanical treatment / abrasion of large surfaces	Surface grinding, smoothing of concrete walls and floors, cutting concrete blocks using masonry saw	100
Mechanical treatment / abrasion of small sized surfaces	Using hand-held grinders to remove mortar	30

Mechanical pulverization of stones	Using power tools like jack hammers to demolish small surfaces, recess millers	10
Manual pulverization or treatment / abrasion of small sized objects	Use of non-powered tools like hammer or chisel, manual polishing	3
Careful breaking stones	Mechanical tile breaking	0.3

Classes and related exposure weights representing emission potential for fracturing and abrasion of metal objects.

Description	Examples	Exposure weights
Mechanical abrasion or fracturing of metal resulting in small amount of dust	sanding metal objects. grinding steel	3
Mechanical abrasion or fracturing of metal resulting in very limited amount of dust	shredding of batteries, sawing or slitting of metal objects,	1
Mechanical deforming of metal	rolling metal sheets	0.1

Question 18.6:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classes and related exposure weights representing emission potential for containment during fracturing and abrasion of wood.

Classification	Examples	Assigned value
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosed cover on a circular saw (relatively small openings are possible)	0.3

Classes and related exposure weights representing emission potential for containment during fracturing and abrasion of stone.

Classification	Examples	Assigned value
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosed stone crushing machine (relatively small openings are possible)	0.3

Classes and related exposure weights representing process containment during fracturing and abrasion of metal objects.

Classification	**Examples**	**Exposure weights**
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosed cover on a battery shredding process (relatively small openings are possible)	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.
Select 'open process' here if the localized control 'containment without extraction' or 'glove boxes/bags' will be selected in the subsequent question on localized controls.

4.4.2 Abrasive blasting

Question 19:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Abrasive blasting of very large surfaces
- Abrasive blasting of large surfaces
- Abrasive blasting of small parts
- Micro-abrasive blasting

Exposure weights for activity emission potential of Activity Class 'abrasive blasting'.

Description	**Example**	**Exposure weight**
Abrasive blasting of very large surfaces	Removing (anti-fouling) paint from ships or bridges. Abrasive blasting is powered by compressed air.	100
Abrasive blasting of large surfaces	Blasting of e.g. car bodies, trailer frames	30
Abrasive blasting of small parts	Blast cleaning of small statues, bicycle frame parts	10
Micro-abrasive blasting	Small-scale abrasive blasting process in e.g. medical aids (blasting area of about a few cm).	1

Question 19.3:
What is the type of abrasive blasting technique?
Answer:

- Dry abrasive blasting
- Wet abrasive blasting

Exposure weights for the type of abrasive blasting technique.

		Exposure

Description	Example	weight
Dry abrasive blasting	Abrasive blasting is powered by compressed air.	1
Wet abrasive blasting	Includes systems where a mixture of abrasive and water is propelled by compressed air, where water is added to abrasive blasting nozzle, or water jet stripping systems.	0.3

Question 19.5:
What is the direction of abrasive blasting?
Answer:

- Abrasive blasting in any direction (including upwards)
- Only horizontal or downward blasting
- Only downward blasting

Exposure weights for abrasive blasting direction during the activity emission potential of Activity Class ‘abrasive blasting’.

Description	Exposure weight
Abrasive blasting in any direction (including upwards)	3
Only horizontal and downward blasting	1
Only downward blasting	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
For this activity class, exposure is estimated to the solid material (or any liquid in or on the surface of the solid matrix) that is being abraded.
The categories are in rank order with activities generating highest emission levels at the top.

4.4.3 Impaction on contaminated solid objects

Question 20:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Impaction on substantially and visibly contaminated objects (layers of more than 0.5 kg).
- Impaction on objects with visible residual dust
- Impaction on objects with limited visible residual dust
- Impaction on slightly contaminated (layers of less than few grams) objects
- Impaction on apparently clean objects

Classes and related exposure weights for activity emission potential of Activity Class ‘Impaction on contaminated solid object’

Description	Examples	Exposure weight

Impaction on substantially and visibly contaminated objects (layers of more than 0.5 kg).	Impaction on heavily contaminated filters	3
Impaction on objects with visible residual dust	Hammering on contaminated objects	1
Impaction on objects with limited visible residual dust	Impaction on limited contaminated drums or transfer line.	0.3
Impaction on slightly contaminated (layers of less than few grams) objects	Impaction on objects after closed filling operations.	0.1
Impaction on apparently clean objects	Impaction on drums coming out of a cleaning machine	0.001

Question 20.5:
What is the type of handling?
Answer:
Dropdown list with following possibilities:

- Heavy mechanical impaction
- Normal impaction (manual or light mechanical)

Classes and related exposure weights for type of handling for activity emission potential of Activity Class ‘Impaction on contaminated solid object’

Description	**Examples**	**Exposure weight**
Heavy mechanical impaction	Hydraulic hammers.	3
Normal impaction (manual or light mechanical)	Manual hammering, beating carpets	1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
For this activity class, exposure is estimated to the contamination on the surface or object that is impacted upon.
The categories are in rank order with activities generating highest emission levels at the top.

4.4.4 Handling of contaminated solid objects or paste

Question 21:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Handling of substantially and visibly contaminated objects (layers of more than 0.5 kg).
- Handling of objects with visible contamination (object covered with fugitive dust from surrounding dusty activities)
- Handling of objects with limited residual dust (thin layer visible)
- Handling of slightly contaminated (layers of less than few grams) objects
- Handling of apparently clean objects

Classes and related exposure weights for activity emission potential of activity subclass ‘Handling of contaminated solid objects or pastes’

Description	Examples	Exposure weight
Handling of substantially and visibly contaminated objects (layers of more than 0.5 kg).	Stacking cement bags with dust contamination (leakage from bag valve), disposal of empty contaminated bags, disposal of heavily contaminated filters, maintenance of heavily contaminated equipment	1
Handling of objects with visible contamination (object covered with fugitive dust from surrounding dusty activities)	Transport of contaminated wooden objects, carrying contaminated bags, changing contaminated filters	0.3
Handling of objects with limited residual dust (thin layer visible)	Transportation of drums. Coupling/decoupling of transfer line. Transport of contaminated metal objects. Replacing filters.	0.1
Handling of slightly contaminated (layers of less than few grams) objects	Handling of slightly contaminated glass bottles or plastic kegs. Packaging of objects after closed filling operations.	0.03
Handling of apparently clean objects	Drums coming out of a cleaning machine	0.001

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
For this activity class, exposure is estimated to the contamination on the surface or object.
The categories are in rank order with activities generating highest emission levels at the top.

Question 21.5:

How are contaminated objects or pastes handled?

Answer:

Dropdown list with following possibilities:

- Handling that departs from regular work procedures and involves large amounts of energy (e.g. rough handling or throwing of bags)
- Normal handling, involves regular work procedures.
- Careful handling, involves workers showing attention to potential danger, error or harm and carrying out the activity in a very exact and thorough (or cautious) manner.

Classes and related exposure weights for type of handling.

Description	Exposure weights
Handling that departs from regular work procedures and involves large amounts of energy (e.g. rough handling or throwing of bags)	3
Normal handling, involves regular work procedures.	1

Careful handling, involves workers showing attention to potential danger, error or harm and carrying out the activity in a very exact and thorough (or cautious) manner.	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.4.5 Spray application of powders

Question 22:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Powder coating
- Dusting using blower

Classes and related exposure weights for activity emission potential of Activity Class 'spray application of powders'.

Description	**Example**	**Exposure weights**
Powder coating	Powder spraying using electrostatic spray gun	10
Dusting using blower	Dusting crops with knapsack dust blower	3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Question 22.5:
What is the spray direction?
Answer:

- Spraying in any direction (including upwards)
- Only horizontal or downward spraying
- Only downward spraying

Classes and related exposure weights for spray direction.

Description	**Exposure weights**
Spraying in any direction (including upwards)	3
Only horizontal or downward spraying	1
Only downward spraying	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.

The categories are in rank order with activities generating highest emission levels at the top.

4.4.6 Movement and agitation of powders, granules or pelletized material

Question 23:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:
- Movement and agitation of 1000 kg or more
- Movement and agitation of 100 - 1000 kg
- Movement and agitation of 10 - 100 kg
- Movement and agitation of 1 - 10 kg
- Movement and agitation of 0.1 - 1 kg
- Movement and agitation of 10 - 100 gram
- Movement and agitation of < 10 gram

Classes and related exposure weights for activity emission potential of Activity Class ‘movement and agitation of powders, granules or pelletized material)’

Description	**Example activities**	**Exposure weight**
Movement and agitation of 1000 kg or more	Sieving big bag volumes in large production plants (e.g. sieving peat moss)	30
Movement and agitation of 100 - 1000 kg	Cleaning large heaps of dust or debris (after demolition) Sieving, mixing or blending in vessels	10
Movement and agitation of 10 - 100 kg	Cleaning heavily contaminated floors (e.g. after dusty activities like bagging or abrasion) Sieving, mixing or blending in large buckets	3
Movement and agitation of 1 - 10 kg	Cleaning floors (sweeping) covered with fugitive dust Manual sieving, mixing or blending	1
Movement and agitation of 0.1 - 1 kg	Using brush and dustpan to clean up small spills Manual sieving, mixing or blending	0.3
Movement and agitation of 10 - 100 gram	Using brush and dustpan to clean up small spills Manual sieving, mixing or blending	0.1
Movement and agitation of < 10 gram	Cleaning valves / machinery / equipment with wipe Mixing on laboratory scale	0.03

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Question 23.5:
What is the level of agitation?

Answer:

Dropdown list with following possibilities:

- Application of compressed air
- Other handling with high level of agitation
- Handling with low level of agitation

Classes and related exposure weights for the level of agitation

Description	**Examples**	**Exposure weight**
Application of compressed air	Using compressed air to clean e.g. machines	30
Other handling with high level of agitation	Sweeping of floors, sieving, mechanical mixing	3
Handling with low level of agitation	Manual mixing	1

Question 23.7:

What is the level of containment of the process?

Answer:

Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	**Examples**	**Exposure weight**
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Contained sieving of big bags with only small opening	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.
Select ‘open process’ here if the localized control ‘containment without extraction’ or ‘glove boxes/bags’ will be selected in the subsequent question on localized controls.

4.4.7 Transfer of powders, granules or pelletized material

4.4.7.1 Falling powders

Question 24:

Which of the situations below does best represent your activity?

Answer:

Dropdown list with following possibilities:

- Transferring more than 1000 kg/minute

- Transferring 100 – 1000 kg/minute
- Transferring 10 – 100 kg/minute
- Transferring 1 – 10 kg/minute
- Transferring 0.1 – 1 kg/minute
- Transferring 10 – 100 gram/minute
- Transferring less than 10 gram/minute

Classes and related exposure weights for activity emission potential of Activity Class 'Falling of powdered, granular or pelletized material'.

Description	Examples	Exposure weights
Transferring more than 1000 kg/minute	Large scale transfer with big bags	30
Transferring 100 – 1000 kg/minute	Automated dumping of powders (e.g. auger or conveyer belt)	10
Transferring 10 – 100 kg/minute	Manual dumping of powders	3
Transferring 1 – 10 kg/minute	Scooping activities	1
Transferring 0.1 – 1 kg/minute	Filling bottles	0.3
Transferring 10 – 100 gram/minute	Small-scale scooping for sampling	0.1
Transferring less than 10 gram/minute	Very small scale weighing (fine adjustments) and scooping in laboratory	0.03

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Question 24.5:
What is the type of handling?
Answer:
Dropdown list with following possibilities:

- Routine transfer
- Careful transfer involves workers showing attention to potential danger, error or harm and carrying out the activity in a very exact and thorough (or cautious) manner, e.g. careful weighing in laboratory.

Exposure weights for type of handling

Description	Exposure weight
Routine transfer	1
Careful transfer involves workers showing attention to potential danger, error or harm and carrying out the activity in a very exact and thorough (or cautious) manner, e.g. careful weighing in laboratory	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Question 24.7:
What is the drop height?
Answer:
Dropdown list with following possibilities:

- Drop height > 0.5 m
- Drop height < 0.5 m

Exposure weights for drop height

Description	**Exposure weight**
Drop height > 0.5 m	3
Drop height < 0.5 m	1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The drop height is measured from the bottom of the dumping opening to the top of the receiving object or surface.

Question 24.8:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	**Examples**	**Exposure weight**
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Dumping powders in a big bag through a small dumping opening	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.
Select 'open process' here if the localized control 'containment without extraction' or 'glove boxes/bags' will be selected in the subsequent question on localized controls.

4.4.7.2 Vacuum transfer of powders

Question 24.9.1:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Transferring more than 1000 kg/minute
- Transferring 100 – 1000 kg/minute
- Transferring 10 – 100 kg/minute
- Transferring 1 – 10 kg/minute
- Transferring 0.1 – 1 kg/minute
- Transferring 10 – 100 gram/minute
- Transferring less than 10 gram/minute

Classes and related exposure weights for activity emission potential of sub Activity Class 'Vacuum transfer of powders'.

Description	**Examples**	**Exposure weights**
Transferring more than 1000 kg/minute	Large scale vacuum transfer from large vessels	3
Transferring 100 – 1000 kg/minute		1
Transferring 10 – 100 kg/minute		0.3
Transferring 1 – 10 kg/minute		0.1
Transferring 0.1 – 1 kg/minute		0.03
Transferring 10 – 100 gram/minute		0.01
Transferring less than 10 gram/minute	Micro powder transfer systems	0.003

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Question 24.9.2:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classes and related exposure weights representing process containment during vacuum transfer of powders, granules or pelletized material

Classification	**Examples**	**Exposure weights**
Open process	Vacuum transfer from open reservoir to enclosed reservoir	1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Vacuum transfer from reservoir with small opening to enclosed reservoir	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.
Select 'open process' here if the localized control 'containment without extraction' or 'glove boxes/bags' will be selected in the subsequent question on localized controls.

4.4.8 Compressing of powders, granules or pelletized material

Question 25:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Compressing more than 1000 kg/minute
- Compressing 100 – 1000 kg/minute
- Compressing 10 – 100 kg/minute
- Compressing 1 – 10 kg/minute
- Compressing 0.1 – 1 kg/minute
- Compressing 10 – 100 gram/minute
- Compressing less than 10 gram/minute

Classes and related exposure weights for activity emission potential of Activity Class 'Compressing of powders, granules or pelletized material'

Description	**Examples**	**Exposure weights**
Compressing more than 1000 kg/minute.	Large scale bulk compression of soil or wood pellets	30
Compressing 100 – 1000 kg/minute		10
Compressing 10 – 100 kg/minute		3
Compressing 1 – 10 kg/minute		1
Compressing 0.1 – 1 kg/minute		0.3
Compressing 10 – 100 gram/minute		0.1
Compressing less than 10 gram/minute	Very small scale tabletting, granulation	0.03

Question 25.3:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	**Examples**	**Exposure weight**
Open process		1.0
Handling that reduces contact between product and adjacent air.	Enclosed tabletting machine (relatively small openings are possible)	0.3

Note: This does not include processes that are fully contained by localized controls (see next questions).

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.
Select 'open process' here if the localized control 'containment without extraction' or 'glove boxes/bags' will be selected in the subsequent question on localized controls.

4.4.9 Fracturing of powders, granules or pelletized material

[Note: when this activity class is selected, the dustiness category (Question 5) should be overruled and set to 'fine dust' (assigned value = 0.3)]

Question 25.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Fracturing more than 1000 kg/minute
- Fracturing 100 – 1000 kg/minute
- Fracturing 10 – 100 kg/minute
- Fracturing 1 – 10 kg/minute
- Fracturing 0.1 – 1 kg/minute
- Fracturing 10 – 100 gram/minute
- Fracturing less than 10 gram/minute

Description	**Examples**	**Exposure weights**
Fracturing more than 1000 kg/minute	Large scale bulk milling	30
Fracturing 100 – 1000 kg/minute		10
Fracturing 10 – 100 kg/minute		3
Fracturing 1 – 10 kg/minute		1
Fracturing 0.1 – 1 kg/minute		0.3
Fracturing 10 – 100 gram/minute		0.1
Fracturing less than 10 gram/minute	Very small scale crushing / testing tablets, de-lumping (breaking up products)	0.03

Question 25.8:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	Examples	Exposure weight
Open process	Bulk milling in an open surface	1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosed tablet crushing (relatively small openings are possible)	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.
Select 'open process' here if the localized control 'containment without extraction' or 'glove boxes/bags' will be selected in the subsequent question on localized controls.

4.4.10 Spray application of liquids

4.4.10.1 Surface spraying of liquids

Question 26:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- High application rate (> 3 l/minute)
- Moderate application rate (0.3 - 3 l/minute)
- Low application rate (0.03 – 0.3 l/minute)
- Very low application rate (< 0.03 l/minute)

Classes and related exposure weights for application emission potential of Activity Subclass 'surface spraying of liquids'.

Description	Examples	Aerosol exposure weights (incl. powders dissolved in a liquid)	Vapour exposure weights
High application rate (> 3 l/minute)	Tractor mounted spraying	3	3
Moderate application rate (0.3 - 3 l/minute)	Paint spraying of e.g. ships	1	1
Low application rate (0.03 – 0.3 l/minute)	Pest control operations	0.3	0.3
Very low application rate (< 0.03 l/minute)	Spot spraying using e.g. controlled droplet application	0.1	0.1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
This activity class includes the spraying of liquids onto surfaces or objects (e.g. paint spraying).
The categories are in rank order with activities generating highest emission levels at the top.

Question 26.5:

What is the spray direction?

Answer:

- Spraying in any direction (including upwards)
- Only horizontal or downward spraying
- Only downward spraying

Classes and related exposure weights for spray direction.

Description	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Spraying in any direction (including upwards)	3	3
Only horizontal or downward spraying	1	1
Only downward spraying	0.3	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Question 26.7:

What is the spray technique?

Answer:

- Spraying with high compressed air use
- Spraying with no or low compressed air use

Classes and exposure weights for spray technique

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Spraying with high compressed air use	Air blast pesticide spraying of e.g. tree nursery	3	3
Spraying with no or low compressed air use	Paint spraying using HVLP or airless techniques; pest control operations using backpack	1	1

4.4.10.2 Spraying of liquids in a space

Question 27:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large scale space spraying
- Small scale space spraying

Classes and related exposure weights for spraying of liquids in a space.

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weight**
Large scale space spraying	Fogging	10	10
Small scale space spraying	Fly spray	1	1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
This activity class includes the spraying of liquids into an open space (e.g. fogging or fly spray).
The categories are in rank order with activities generating highest emission levels at the top.

4.4.11 Activities with open liquid surfaces and open reservoirs

4.4.11.1 Activities with relatively undisturbed surfaces (no aerosol formation)

Question 28:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Open surface > 3 m^2
- Open surface 1 - 3 m^2
- Open surface 0.3 - 1 m^2
- Open surface 0.1 – 0.3 m^2
- Open surface < 0.1 m^2

Classes and related exposure weights for activity emission potential of Activity Subclass ‘Activities with (evaporating) bath’

Description	**Examples**	**Aerosol exposure weights (incl. powders**	**Vapour exposure weights**

		dissolved in a liquid)	
Open surface > 3 m^2	Tank dipping	0.001	0.3
Open surface 1 - 3 m^2		0.001	0.1
Open surface 0.3 - 1 m^2		0.001	0.03
Open surface 0.1 – 0.3 m^2		0.001	0.01
Open surface < 0.1 m^2	Manual stirring in paint can Storage of laboratory samples	0.001	0.003

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.4.11.2 Activities with agitated surfaces

Question 28.3:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Open surface > 3 m^2
- Open surface 1 - 3 m^2
- Open surface 0.3 - 1 m^2
- Open surface 0.1 – 0.3 m^2
- Open surface < 0.1 m^2

Classes and related exposure weights for surface area

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Open surface > 3 m^2	Bath with gas bubbling (e.g. electroplating) Bath with ultrasonic cleaning	0.3	1.0
Open surface 1 - 3 m^2		0.1	0.3
Open surface 0.3 - 1 m^2		0.03	0.1

Open surface 0.1 – 0.3 m^2		0.01	0.03
Open surface < 0.1 m^2	Mechanical mixing in paint can, mechanical mixing very small amounts in e.g. laboratory	0.003	0.01

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.4.12 Handling of contaminated objects

Question 28.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Activities with treated/contaminated objects (surface > 3 m2)
- Activities with treated/contaminated objects (surface 1-3 m2)
- Activities with treated/contaminated objects (surface 0.3-1 m2)
- Activities with treated/contaminated objects (surface 0.1-0.3 m2)
- Activities with treated/contaminated objects (surface <0.1 m2)

Classes and related exposure weights for activity emission potential of Activity Subclass 'handling of contaminated objects'

Description		**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Activities with treated/contaminated objects (surface > 3 m^2)	Handling large treated and drying objects	0.001	0.3
Activities with treated/contaminated objects (surface 1-3 m^2)	Maintenance of fuel pumps; coupling and decoupling of hoses or (drilling) equipment	0.001	0.1
Activities with treated/contaminated objects (surface 0.3-1 m^2)	Handling small treated and drying objects	0.001	0.03
Activities with treated/contaminated objects (surface 0.1-0.3 m^2)	Handling of contaminated tools	0.001	0.01
Activities with treated/contaminated objects (surface <0.1 m^2)	Handling small tools in laboratory (e.g. pipettes)	0.001	0.003

Question 28.7:
What is the level of contamination of the surface of the objects?
Answer:

Dropdown list with following possibilities:
- Contamination > 90 % of surface
- Contamination 10-90 % of surface
- Contamination < 10 % surface

Classes and related exposure weights for level of contamination of objects

Description	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Contamination > 90 % of surface	1	1
Contamination 10-90 % of surface	0.3	0.3
Contamination < 10 % surface	0.1	0.1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.4.12.1 Spreading of liquid products

Question 29:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:
- Spreading of liquids at surfaces or work pieces > 3 m2 / hour
- Spreading of liquids at surfaces or work pieces 1.0 - 3.0 m2 / hour
- Spreading of liquids at surfaces or work pieces 0.3 - 1.0 m2 / hour
- Spreading of liquids at surfaces or work pieces 0.1 - 0.3 m2 / hour
- Spreading of liquids at surfaces or work pieces < 0.1 m2 / hour

Classes and related exposure weights for activity emission potential of Activity Subclass ‘Spreading of liquid products’

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Spreading of liquids at surfaces or work pieces > 3 m^2 / hour	Painting of walls or ships, removing (large) graffiti, cleaning of oil residue from bulk tanks	0.1	0.3

Spreading of liquids at surfaces or work pieces 1.0 - 3.0 m^2 / hour	Degreasing machines, painting of walls	0.1	0.1
Spreading of liquids at surfaces or work pieces 0.3 - 1.0 m^2 / hour	Painting of casings using a roller or brush, gluing e.g. shoe soles, degreasing or cleaning small machines/tools	0.1	0.03
Spreading of liquids at surfaces or work pieces 0.1 - 0.3 m^2 / hour	Spot degreasing (small objects like knifes), gluing stickers and labels	0.01	0.01
Spreading of liquids at surfaces or work pieces < 0.1 m^2 / hour	Small scale spreading e.g. in laboratory	0.001	0.003

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.4.13 Application of liquids in high speed processes (e.g. rotating tools)

Question 30:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large-scale activities involving high speed movements
- Small-scale activities involving high speed movements

Classes and related exposure weights representing emission potential for high speed processes.

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weight**
Large-scale activities involving high speed movements	Rotating pipes in oil drilling, rotating press during printing, application of metal working fluids in machining large work pieces	3	3
Small-scale activities involving high speed movements	Application of MWF in machining of small scale work pieces (e.g. < 10 kg)	1	1

Question 30.5:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process: no separation between process and worker
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	Examples	Exposure weight
Open process: no separation between process and worker		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosing panels around machining process	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.
Select 'open process' here if the localized control 'containment without extraction' or 'glove boxes/bags' will be selected in the subsequent question on localized controls.

4.4.14 Transfer of liquid products

4.4.14.1 Bottom loading

Question 32:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Transfer of liquid product with flow of > 1000 l/minute
- Transfer of liquid product with flow of 100 - 1000 l/minute
- Transfer of liquid product with flow of 10 - 100 l/minute
- Transfer of liquid product with flow of 1 - 10 l/minute
- Transfer of liquid product with flow of 0.1 - 1 l/minute
- Transfer of liquid product with flow of < 0.1 l/minute

Classes and related exposure weights for activity emission potential of Activity Class 'falling liquids'.

Description	Examples	Aerosol exposure weights (incl. powders dissolved in a liquid)	Vapour exposure weights
Transfer of liquid product with flow of > 1000 l/minute	Loading of tanker at bulk terminal (boats, rail car or truck)	0.001	0.1
Transfer of liquid product with flow of 100 - 1000 l/minute	Loading of aircraft (under wing)	0.001	0.03
Transfer of liquid product with flow of 10 - 100 l/minute	Transfer of additives in tanker	0.001	0.01

Transfer of liquid product with flow of 1 - 10 l/minute	Transfer of additives in tanker	0.001	0.003
Transfer of liquid product with flow of 0.1 - 1 l/minute	Transfer of additives in tanker	0.001	0.001
Transfer of liquid product with flow of < 0.1 l/minute	Transfer of additives in tanker	0.001	0.001

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.4.14.2 Falling liquids

Question 33:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Transfer of liquid product with flow of > 1000 l/minute
- Transfer of liquid product with flow of 100 - 1000 l/minute
- Transfer of liquid product with flow of 10 - 100 l/minute
- Transfer of liquid product with flow of 1 - 10 l/minute
- Transfer of liquid product with flow of 0.1 – 1 l/minute
- Transfer of liquid product with flow of < 0.1 l/minute

Exposure weights for activity emission potential of Activity Class ‘falling liquids’ in case of splash loading.

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Transfer of liquid product with flow of > 1000 l/minute	Loading of tanker at bulk terminal (boats, rail car or truck)	0.1	0.1
Transfer of liquid product with flow of 100 - 1000 l/minute	Filling of drums	0.03	0.03
Transfer of liquid product with flow of 10 - 100 l/minute	(Re)fuelling cars, manual topping up, manual calibration of fuel pump	0.01	0.01
Transfer of liquid product with flow of 1 - 10 l/minute	Filling of bottles, filling of paint gun	0.003	0.003
Transfer of liquid product with flow of 0.1 – 1 l/minute	Filling of bottles, filling of paint gun	0.001	0.001
Transfer of liquid product with flow of < 0.1 l/minute	Transfer of small amounts in laboratory	0.001	0.001

Question 33.5:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	**Examples**	**Exposure weight**
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Transfer of liquid through a small filling opening (e.g. refuelling of vehicles)	0.3

Question 34:
Is the transfer of liquid performed by splash or submerged loading?
Answer:
Dropdown list with following possibilities:

- Splash loading, where the liquid dispenser remains at the top of the reservoir and the liquid splashes freely
- Submerged loading, where the liquid dispenser remains below the fluid level reducing the amount of aerosol formation

Classes and related exposure weights representing submerged and splash loading.

Classification	**Exposure weights**
Splash loading, where the liquid dispenser remains at the top of the reservoir and the liquid splashes freely	3.0
Submerged loading, where the liquid dispenser remains below the fluid level reducing the amount of aerosol formation	1.0

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.
Select ‘open process’ here if the localized control ‘containment without extraction’ or ‘glove boxes/bags’ will be selected in the subsequent question on localized controls.

4.4.15 Smelting or melting of metal

4.4.15.1 Smelting of metal

Question 35:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Smelting in an inherently closed process)

The actual smelting process has to be fully enclosed, including the loading/charging operation, and operators spend most of their time in control rooms during routine operation. This means that exposures are possible only during regular control inspections and tapping, which are part of activity class: “Pouring or tapping of molten metals”.

Classification	**Examples**	**Exposure weight**
Smelting in an inherently closed process		0.001

[If this activity subclass is selected, the answer to the localized control question cannot be ‘containment – no extraction’, ‘enclosing hoods’ or ‘glove boxes/bags’.]

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.4.15.2 Melting of metal

Question 35.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large scale melting (> 10 tonnes)
- Medium scale melting (1-10 tonnes)
- Small scale melting (100 – 1000 kg)
- Very small scale melting (< 100 kg)

Classification	**Examples**	**Exposure weight**
Large scale melting (> 10 tonnes)	> 10 tonnes	3
Medium scale melting (1-10 tonnes)	1-10 tonnes	1
Small scale melting (100 – 1000 kg)	100 – 1000 kg	0.3
Very small scale melting (< 100 kg)	< 100 kg	0.1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.4.16 Pouring or tapping of molten metal (including melt drossing and dipping in molten metal)

4.4.16.1 Pouring or tapping of molten metal

Question 36:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large scale pouring or tapping (> 10 tonnes)
- Medium scale pouring or tapping (1-10 tonnes)
- Small scale pouring or tapping (100 – 1000 kg)

- Very small scale pouring or tapping (< 100 kg)

Classification	Examples	Exposure weight
Large scale pouring or tapping (> 10 tonnes)	> 10 tonnes	10
Medium scale pouring or tapping (1-10 tonnes)	1-10 tonnes	3
Small scale pouring or tapping (100 – 1000 kg)	100 – 1000 kg	1
Very small scale pouring or tapping (< 100 kg)	< 100 kg	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.4.16.2 Dipping in molten metal

Question 36.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Open surface > 3 m2
- Open surface 1 - 3 m2
- Open surface 0.3 - 1 m2
- Open surface 0.1 – 0.3 m2
- Open surface < 0.1 m2

Classification	Examples	Exposure weight
Open surface > 3 m^2		3
Open surface 1 - 3 m^2		1
Open surface 0.3 - 1 m^2		0.3
Open surface 0.1 – 0.3 m^2		0.1
Open surface < 0.1 m^2		0.03

Question 36.7:
Is a flux used as a protective layer on the molten metal?
Answer:
Dropdown list with following possibilities:

- No use of flux
- Use of flux as protective layer on molten metal

Classification	Examples	Exposure weight
No use of flux		1
Use of flux as protective layer on molten metal	Fluxed bath	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.4.17 Sintering, roasting, oxidation or burning

4.4.17.1 Sintering

Question 37:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large scale sintering (> 10 tonnes)
- Medium scale sintering (1-10 tonnes)
- Small scale sintering (100 – 1000 kg)
- Very small scale sintering (< 100 kg)

Classification	**Examples**	**Exposure weight**
Large scale sintering (> 10 tonnes)	> 10 tonnes	10
Medium scale sintering (1-10 tonnes)	1-10 tonnes	3
Small scale sintering (100 – 1000 kg)	100 – 1000 kg	1
Very small scale sintering (< 100 kg)	< 100 kg	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.4.17.2 Roasting

Question 37.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large scale roasting (> 10 tonnes)
- Medium scale roasting (1-10 tonnes)
- Small scale roasting (100 – 1000 kg)
- Very small scale roasting (< 100 kg)

Classification	**Examples**	**Exposure weight**
Large scale roasting (> 10 tonnes)	> 10 tonnes	10
Medium scale roasting (1-10 tonnes)	1-10 tonnes	3
Small scale roasting (100 – 1000 kg)	100 – 1000 kg	1
Very small scale roasting (< 100 kg)	< 100 kg	0.3

Question 37.7:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:
- Tunnel oven
- Enclosed roasting furnace

Classification	**Examples**	**Exposure weight**
Tunnel oven	Tunnel oven,	1
Enclosed roasting furnace	Rotary kiln	0.001

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.4.17.3 Oxidation, burning

Question 38:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:
- Large scale oxidation, burning (> 10 tonnes)
- Medium scale oxidation, burning (1-10 tonnes)
- Small scale oxidation, burning (100 – 1000 kg)
- Very small scale oxidation, burning (< 100 kg)

Classification	**Examples**	**Exposure weight**
Large scale oxidation, burning (> 10 tonnes)		10
Medium scale oxidation, burning (1-10 tonnes)	Production of speciality products, such as high purity oxides	3
Small scale oxidation, burning (100 – 1000 kg)		1
Very small scale oxidation, burning (< 100 kg)	Rotary furnaces	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.4.18 Spray application of hot metal

Question 38.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:
- Deposition rate > 5 kg/hr
- Deposition rate < 5 kg/hr

Classification	**Examples**	**Exposure weight**
Deposition rate > 5 kg/hr	Detonation gun	0.03
Deposition rate < 5 kg/hr	Plasma spraying	0.01

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.4.19 Atomisation

Question 39:

[There is no question needed here. This is just one class. When this sub activity class is selected, show the following text:

Metallic powders can be obtained by atomisation of a furnace melt (melt atomisation). This can be achieved by a variety of means such as by spraying molten metal under pressure through a nozzle into a variety of media {liquid atomisation (water or oil) or gas atomisation (air, nitrogen or argon) techniques} and by more specialised techniques including centrifugal atomisation {pouring a melt onto a rotating disc or using the Rotating Electrode Process (REP)}, ultrasound and pressure. This process requires full enclosure to achieve atomisation and powder formation.

Classification	**Examples**	**Exposure weight**
Atomisation in enclosed tank		0.001

[If this activity subclass is selected, the answer to the localized control question cannot be 'containment – no extraction', 'enclosing hoods' or 'glove boxes/bags'.]

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.4.20 Compressing of, impacting on, or hardening of metal objects

Question 40:

Which of the situations below does best represent your activity?

Answer:

Dropdown list with following possibilities:

- Mechanical hot forging, hot rolling or quenching of large scale metal objects
- Manual forging, small scale mechanical rolling or quenching of smaller sized hot metal objects

Classification	**Examples**	**Exposure weight**
Mechanical hot forging, hot rolling or quenching of large scale metal objects	Hot rolling of slabs > 5000 kg Hot forging of metal objects that cannot be lifted by hand (> 50 kg)	10
Manual forging, small scale mechanical rolling or quenching of smaller sized hot	Quenching knives or swords Manual forging (e.g. horse smith	1

metal objects	using hammer and anvil) Hot rolling of rods < 5000 kg

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

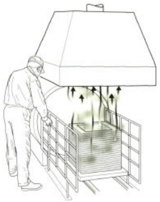
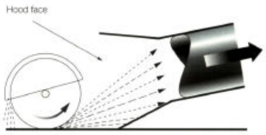
4.5 Localized controls (FF source)

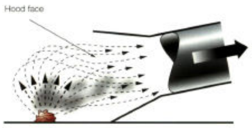
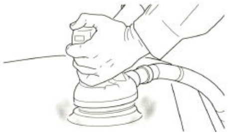
Question 42:
Are there any control measures in close proximity of the far field emission source intended to minimize emissions from the source? *[Warning text: "the control measure should cover the whole activity"].*
Answer:
Dropdown list with following possibilities:

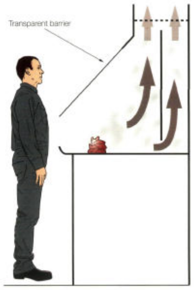
- No localized controls -> go to question 43
- Suppression techniques *[This class should only be visible if the answer to question 3 = "*Powdered, granular or pelletized material" or "Solid objects"] -> *go to separate dropdown list for suppression techniques below*
    - Knockdown suppression
    - Wetting at the point of release
- Containment – no extraction *[If this class is selected the answer to the containment question in the activity emission potential should be overruled and set to 'open process']*
    - Low level containment
    - Medium level containment
    - High level containment
- Local exhaust ventilation (LEV) -> *go to separate dropdown list for LEV below*
    - Receiving hoods -> *go to separate dropdown list for receiving hoods below*
        - Canopy hood
        - Other receiving hoods
    - Capturing hoods -> *go to separate dropdown list for capturing hoods below*
        - Movable capturing hood
        - Fixed capturing hood
        - On-tool extraction
    - Enclosing hoods -> *go to separate dropdown list for enclosing hoods below.*
        - Fume cupboard
        - Horizontal/downward laminar flow booth
        - Other enclosing hoods
    - Other LEV systems
- Glove boxes and glove bags *[If this class is selected the answer to the containment question in the activity emission potential should be overruled and set to 'open process']*
    - Glove bags
        - Glove bags (non-ventilated)
        - Glove bags (ventilated or kept under negative pressure)
    - Glove boxes
        - Low specification glove box
        - Medium specification glove box
        - High specification glove box / isolator
- Vapour recovery systems

Descriptions and assigned values of each category are given in the table below.

Classification	Description	Assigned typical value	Guidance images
No localized controls	No control measures in close proximity of the source.	1	
Suppression techniques			
Knockdown suppression *[This class should only be visible if the answer to question 3 = “*Powdered, granular or pelletized material” or “Solid objects”]	Post generation suppression of airborne contaminants to reduce dust levels. Knockdown of a contaminant after it has been emitted.	0.7	
Wetting at the point of release *[This class should only be visible if the answer to question 3 = “*Powdered, granular or pelletized material” or “Solid objects”]	Wetting systems that wet the process at the point of release (focusing on the emission source) to agglomerate and bind the fine particles to prevent dust from being dispersed into the workroom air.	0.1	
Containment - no extraction	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. This class reflects “add on” enclosures and does not include inherently closed systems (like pipelines)		
- Low level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The process is contained with a loose lid or cover, which is not air tight. This includes tapping molten metal through covered launders and placing a loose lid on a ladle This class also includes bags or liners fitted around transfer points from source to receiving vessel. These include Muller seals, Stott head and single bag, and associated clamps and closures.	0.1	

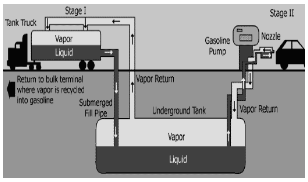
- Medium level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The material transfer is enclosed with the receiving vessel being docked or sealed to the source vessel. Examples include sealing heads, transfer containers and multiple o-rings. Inflatable packing head with continuous liner ensures a seal is maintained during the powder transfer and the continuous plastic liner prevents direct contact with the product. The correct type of tie off must be used.	0.01	
- High level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The substance is contained within a sealed and enclosed system. This class includes metal smelting furnaces or atomisation units. The material transfer is entirely enclosed with high containment valves (e.g. split butterfly valves and direct couplings, which consist of two sections which connect together to allow the opening of the valve). At the end of the material transfer the two halves are separated, forming a seal on both the process equipment and the material container. The system is designed to minimise the surface area which can contact the material or pairs of valves with wash space between them.	0.001	
Local exhaust ventilation (LEV) - Receiving hoods			
> Canopy hoods	A canopy hood placed over a hot process to receive the plume of contaminant-laden air given off. For cold processes with no thermal uplift, canopy hoods are ineffective.	0.5	
> Other receiving hoods	A receiving hood can be applied wherever a process produces a contaminant cloud with a strong and predictable direction (e.g. a grinding wheel). The contaminant cloud is propelled into the hood by process-	0.2	

	induced air movement. The face of the hood must be big enough to receive the contaminant cloud and the extraction empties the hood of contaminated air at least as fast as it is filled.		
- Capturing hoods			
> Movable capturing hoods	Movable LEV systems such as hoods with extendable arms. The design of the system does not prevent work being performed outside the capture zone of the system and worker behaviour can influence the effectiveness of the system.	0.5	
> Fixed capturing hoods	Fixed capturing hoods located in close proximity of and directed at the source of emission. The design is such that the work is performed in the capture zone of the ventilation system and the capture is indicated at the workplace.	0.1	
> On-tool extraction	LEV systems integrated in a process or equipment that cannot be separated from the primary emission source.	0.1	
- Enclosing hoods			
> Fume cupboard	Any form of permanent encapsulation or encasing of the source of which maximally one side is open with a well designed local exhaust ventilation system (e.g. laminar air flow). The design of both the enclosure and the ventilation system is such that the influence of worker behaviour is minimal (e.g. an alarm system prevents the worker from using the fume cupboard in case the system is not working properly).	0.01	
> Horizontal/downward laminar flow booth	In a horizontal laminar flow booth, contaminated air is extracted through holes situated at the rear of the booth which creates a horizontal laminar air flow. The air is filtered prior to being discharged to the atmosphere. The booth contains the source and has maximally one side open. In a downward laminar flow booth, a curtain of descending laminar air flow is created between the ceiling and the rear of the booth where exhaust grills are located in the lower section. The booth	0.1	

	contains the source and has maximally one side open.. Spray rooms and laminar down-flow booths (with the size of a room which contains both the source and the worker) are not considered to be a localised control and will be treated together with the dispersion questions at a later stage.		
> Other enclosing hoods	Any form of permanent encapsulation or encasing of the source of which maximally the front side is open with a proper local exhaust ventilation system.	0.1	
- Other LEV systems	In case the type of local exhaust ventilation system is unknown or not specified, this default LEV category can be selected. Note that this default category results in a low reduction of the estimated personal exposure level. An attempt should be made to more specifically define the type of local exhaust ventilation.	0.5	
Glove bags and glove boxes			
- Glove bags	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way. An adaption piece is necessary between the glove bag and the process equipment. The glove bag must be designed specifically for the task and the quantity of material to be handled. Various other items such as pass-out boxes, inlet filters, and drains are added to meet specific needs. Note: use of glove bags does not negate the need to implement a long term permanent technological solution.		

> Glove bags (non-ventilated)	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way without exhaust ventilation.	0.01	
> Glove bags (ventilated or kept under negative pressure)	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way. The glove bag is maintained with filtration and ventilation at specific flow rates	0.001	
- Glove boxes	Any form of permanent encapsulation or encasing of the source (which are not opened during the given activity) with a well designed local exhaust ventilation system. The design of both the enclosure and the ventilation system is such that the influence of worker behaviour is minimal (e.g. the enclosure cannot be opened before the substance is properly vented).		
> Low specification glove box	A low specification glove box is specified as: • Single chamber, simple access doors or pass box • Not safe change glove • Single HEPA filtered extract air • Not safe change filters • Manual cleaning	0.001	
> Medium specification glove box	A medium specification glove box is specified as: • Two or more chambers if large area bin docking or high dust levels expected • Safe change or push through filters are required • Solid (stainless steel) construction for durability • Size is dependent on the task to be carried out • Safe change filters are required • Air should be single or double HEPA filtered and or exhausted directly to the atmosphere after single HEPA filtration. • The equipment should be maintained under negative pressure and the air flow and filter condition continuously monitored.	0.0003	

	• Emergency air extraction should start up automatically in the event of a leak or a damaged glove. • Interlocked air locks should be used to prevent high dust concentrations in the area of the transfer ports and reduce risk. (escape of the contaminant during transfer of materials into and out of the glove box). • Glove changes should be able to be carried out without breaking containment • Waste disposal ports are required. Correct sealing of continuous liners. • Manual cleaning	
> High specification glove box	A high specification glove box is specified as: • Two or more chambers • Safe change filters are required • Stainless steel construction • Size is dependent on the task to be carried out • Safe change filters are required • Air should be single or double HEPA filtered and or exhausted directly to the atmosphere after single HEPA filtration. • The equipment should be maintained under negative pressure and the air flow and filter condition continuously monitored. • Emergency air extraction should start up automatically in the event of a leak or a damaged glove. • Interlocked air locks should be used to prevent the escape of the contaminant during transfer of materials into and out of the glove box. • Glove changes should be able to be carried out without breaking containment • Waste disposal ports are required. • Integrated sampling and contained drum charging • Sealed and high containment transfer ports (contained transfer couplings, rapid transfer ports (RTPs), alpha/beta valves etc.) • Including waste removal and change parts • Wash in place	0.0001

	• Alarmed		
Vapour recovery systems	Reduction of vapour emission during storage, loading and off-loading of gasoline or other liquids, and during re-fuelling of a vehicle, by the combination of a vapour collection system and a vapour control unit. Vapour collection is a passive process where the volume of liquid transferred is equal to the volume of vapour transported back to the tank. The system only works properly when no other escape openings are present.	0.2	

Guidance text:

Select the general type of localized controls present for this emission source.
Depending on your selection you may be required to further define the localized controls.
Spray rooms and laminar down-flow booths (with the size of a room which contains both the source and the worker) are not considered to be a localized control and will be treated together with the dispersion questions at a later stage.

Question 42.5:

Are there any secondary control measures in close proximity of the far field emission source intended to minimize emissions from the source in addition to the primary control measure indicated in the previous question? *[Warning text: "the control measure should cover the whole activity"]*.

Answer:

Dropdown list with following possibilities:

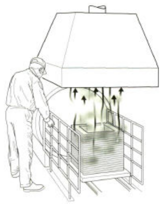
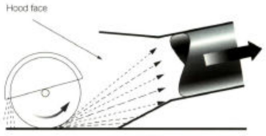
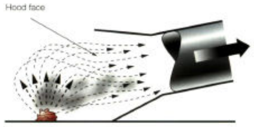
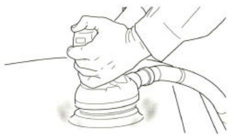
- No secondary localized controls
- Suppression techniques *[This class should only be visible if the answer to question 3 = "*Powdered, granular or pelletized material" or "Solid objects"] -> *go to separate dropdown list for suppression techniques below*
    - Knockdown suppression
    - Wetting at the point of release
- Containment – no extraction *[If this class is selected the answer to the containment question in the activity emission potential should be overruled and set to 'open process']*
    - Low level containment
    - Medium level containment
    - High level containment
- Local exhaust ventilation (LEV) -> *go to separate dropdown list for LEV below*
    - Receiving hoods -> *go to separate dropdown list for receiving hoods below*
        - Canopy hood
        - Other receiving hoods
    - Capturing hoods -> *go to separate dropdown list for capturing hoods below*
        - Movable capturing hood
        - Fixed capturing hood
        - On-tool extraction
    - Enclosing hoods -> *go to separate dropdown list for enclosing hoods below.*
        - Fume cupboard

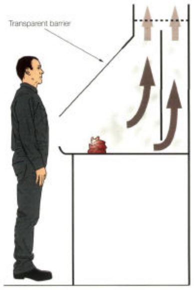
        - Horizontal/downward laminar flow booth
        - Other enclosing hoods
    - Other LEV systems
- Glove boxes and glove bags *[If this class is selected the answer to the containment question in the activity emission potential should be overruled and set to ‘open process’]*
        - Glove bags
            - Glove bags (non-ventilated)
            - Glove bags (ventilated or kept under negative pressure)
        - Glove boxes
            - Low specification glove box
            - Medium specification glove box
            - High specification glove box / isolator
- Vapour recovery systems

Descriptions and assigned values of each category are given in the table below.

Classification	**Description**	**Assigned typical value**	**Guidance images**
No secondary localized controls Suppression techniques	No secondary control measures in close proximity of the source.	1	
Knockdown suppression *[This class should only be visible if the answer to question 3 = “*Powdered, granular or pelletized material” or “Solid objects”]	Post generation suppression of airborne contaminants to reduce dust levels. Knockdown of a contaminant after it has been emitted.	0.7	
Wetting at the point of release *[This class should only be visible if the answer to question 3 = “*Powdered, granular or pelletized material” or “Solid objects”]	Wetting systems that wet the process at the point of release (focusing on the emission source) to agglomerate and bind the fine particles to prevent dust from being dispersed into the workroom air.	0.1	
Containment - no extraction	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. This class reflects “add on” enclosures and does not include inherently closed systems (like pipelines)		
- Low level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The process is contained with a loose lid or cover, which is not air tight. This	0.1	

	includes tapping molten metal through covered launders and placing a loose lid on a ladle This class also includes bags or liners fitted around transfer points from source to receiving vessel. These include Muller seals, Stott head and single bag, and associated clamps and closures.		
- Medium level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The material transfer is enclosed with the receiving vessel being docked or sealed to the source vessel. Examples include sealing heads, transfer containers and multiple o-rings. Inflatable packing head with continuous liner ensures a seal is maintained during the powder transfer and the continuous plastic liner prevents direct contact with the product. The correct type of tie off must be used.	0.01	
- High level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The substance is contained within a sealed and enclosed system. This class includes metal smelting furnaces or atomisation units. The material transfer is entirely enclosed with high containment valves (e.g. split butterfly valves and direct couplings, which consist of two sections which connect together to allow the opening of the valve). At the end of the material transfer the two halves are separated, forming a seal on both the process equipment and the material container. The system is designed to minimise the surface area which can contact the material or pairs of valves with wash space between them.	0.001	
Local exhaust ventilation (LEV) - Receiving hoods			

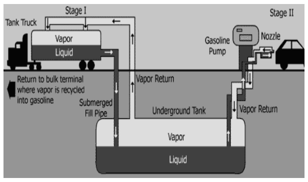
> Canopy hoods	A canopy hood placed over a hot process to receive the plume of contaminant-laden air given off. For cold processes with no thermal uplift, canopy hoods are ineffective.	0.5	
> Other receiving hoods	A receiving hood can be applied wherever a process produces a contaminant cloud with a strong and predictable direction (e.g. a grinding wheel). The contaminant cloud is propelled into the hood by process-induced air movement. The face of the hood must be big enough to receive the contaminant cloud and the extraction empties the hood of contaminated air at least as fast as it is filled.	0.2	
- Capturing hoods			
> Movable capturing hoods	Movable LEV systems such as hoods with extendable arms. The design of the system does not prevent work being performed outside the capture zone of the system and worker behaviour can influence the effectiveness of the system.	0.5	
> Fixed capturing hoods	Fixed capturing hoods located in close proximity of and directed at the source of emission. The design is such that the work is performed in the capture zone of the ventilation system and the capture is indicated at the workplace.	0.1	
> On-tool extraction	LEV systems integrated in a process or equipment that cannot be separated from the primary emission source.	0.1	
- Enclosing hoods			
> Fume cupboard	Any form of permanent encapsulation or encasing of the source of which maximally one side is open with a well designed local exhaust ventilation system (e.g. laminar air flow). The design of both the enclosure and the ventilation system is such that the influence of worker behaviour is minimal (e.g. an alarm system prevents the worker from using the fume cupboard in case the system is not working properly).	0.01	

> Horizontal/downward laminar flow booth	In a horizontal laminar flow booth, contaminated air is extracted through holes situated at the rear of the booth which creates a horizontal laminar air flow. The air is filtered prior to being discharged to the atmosphere. The booth contains the source and has maximally one side open. In a downward laminar flow booth, a curtain of descending laminar air flow is created between the ceiling and the rear of the booth where exhaust grills are located in the lower section. The booth contains the source and has maximally one side open.. Spray rooms and laminar down-flow booths (with the size of a room which contains both the source and the worker) are not considered to be a localised control and will be treated together with the dispersion questions at a later stage.	0.1	
> Other enclosing hoods	Any form of permanent encapsulation or encasing of the source of which maximally the front side is open with a proper local exhaust ventilation system.	0.1	
- Other LEV systems	In case the type of local exhaust ventilation system is unknown or not specified, this default LEV category can be selected. Note that this default category results in a low reduction of the estimated personal exposure level. An attempt should be made to more specifically define the type of local exhaust ventilation.	0.5	

Glove bags and glove boxes

- Glove bags	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way. An adaption piece is necessary between the glove bag and the process equipment. The glove bag must be designed specifically for the task and the quantity of material to be handled. Various other items such as pass-out boxes, inlet filters, and drains are added to meet specific needs. Note: use of glove bags does not negate the need to implement a long term permanent technological solution.		
> Glove bags (non-ventilated)	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way without exhaust ventilation.	0.01	
> Glove bags (ventilated or kept under negative pressure)	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way. The glove bag is maintained with filtration and ventilation at specific flow rates	0.001	
- Glove boxes	Any form of permanent encapsulation or encasing of the source (which are not opened during the given activity) with a well designed local exhaust ventilation system. The design of both the enclosure and the ventilation system is such that the influence of worker behaviour is minimal (e.g. the enclosure cannot be opened before the substance is properly vented).		
> Low specification glove box	A low specification glove box is specified as: • Single chamber, simple access doors or pass box • Not safe change glove • Single HEPA filtered extract air • Not safe change filters • Manual cleaning	0.001	
> Medium specification glove box	A medium specification glove box is specified as: • Two or more chambers if large area bin docking or high dust levels expected	0.0003	

	• Safe change or push through filters are required • Solid (stainless steel) construction for durability. • Size is dependent on the task to be carried out • Safe change filters are required • Air should be single or double HEPA filtered and or exhausted directly to the atmosphere after single HEPA filtration. • The equipment should be maintained under negative pressure and the air flow and filter condition continuously monitored. • Emergency air extraction should start up automatically in the event of a leak or a damaged glove. • Interlocked air locks should be used to prevent high dust concentrations in the area of the transfer ports and reduce risk (escape of the contaminant during transfer of materials into and out of the glove box). • Glove changes should be able to be carried out without breaking containment • Waste disposal ports are required. Correct sealing of continuous liners. • Manual cleaning	
> High specification glove box	A high specification glove box is specified as: • Two or more chambers • Safe change filters are required • Stainless steel construction • Size is dependent on the task to be carried out • Safe change filters are required • Air should be single or double HEPA filtered and or exhausted directly to the atmosphere after single HEPA filtration. • The equipment should be maintained under negative pressure and the air flow and filter condition continuously monitored. • Emergency air extraction should start up automatically in the event of a leak or a damaged glove. • Interlocked air locks should be used to prevent the escape of the contaminant during transfer of	0.0001

	materials into and out of the glove box. • Glove changes should be able to be carried out without breaking containment • Waste disposal ports are required. • Integrated sampling and contained drum charging • Sealed and high containment transfer ports (contained transfer couplings, rapid transfer ports (RTPs), alpha/beta valves etc.) • Including waste removal and change parts • Wash in place • Alarmed		
Vapour recovery systems	Reduction of vapour emission during storage, loading and off-loading of gasoline or other liquids, and during re-fuelling of a vehicle, by the combination of a vapour collection system and a vapour control unit. Vapour collection is a passive process where the volume of liquid transferred is equal to the volume of vapour transported back to the tank. The system only works properly when no other escape openings are present.	0.2	

Guidance text:

Select the secondary type of localized controls present for this emission source.
Depending on your selection you may be required to further define the localized controls.
The system is not protected against any non-existing combinations of localized controls, so be aware to only select a secondary localized control that can be used in combination with the primary localized control indicated in the previous questions.

4.6 Segregation (FF source)

Question 43:

Is the emission source segregated from the work environment by isolation of the source in a segregated room or work area?

Answer:

Dropdown list with following possibilities:

- Partial segregation without ventilation
- Partial segregation with ventilation and filtration of recirculated air
- Complete segregation without ventilation
- Complete segregation with ventilation and filtration of recirculated air
- No segregation

Descriptions and assigned values of each category are given in the table below:

Classification	Description	Assigned value
Partial segregation without ventilation	Sources are partially segregated from the work environment by isolating the source in a separate room (e.g. with open doors and/or windows to the adjacent area). This segregated area is generally not entered by the worker during a given activity or working shift. The air within the separate room is not actively ventilated.	0.7
Partial segregation with ventilation and filtration of recirculated air	Sources are partially segregated from the work environment by isolating the source in a separate room (with open doors and/or windows). This segregated area is generally not entered by the worker during a given activity or working shift. The air within the separate area is actively ventilated and the recirculated air is filtered or there is no air recirculation.	0.3
Complete segregation without ventilation	Sources are completely segregated from the work environment by isolating the source in a fully enclosed and separate room (incl. closed doors & windows). This segregated area is generally not entered by the worker during a given activity or working shift. The air within the separate area is not ventilated.	0.3
Complete segregation with ventilation and filtration of recirculated air	Sources are completely segregated from the work environment by isolating the source in a fully enclosed and separate room (incl. closed doors & windows). The air within the separate area is actively ventilated and the recirculated air is filtered or there is no air recirculation. The segregated area is generally not entered by the worker during a given activity or working shift.	0.1
No segregation	The source is not isolated from the work environment.	1

Guidance text:

Specify the segregation for this emission source then click Next.
Segregation of the source is defined as isolation of sources from the work environment in a separate room without direct containment of the source itself. The segregated area is not entered by the worker during a given activity or working shift.

4.7 Personal enclosure (FF source)

Question 44: [This question should <u>not</u> be asked if the answer to question 16 = 'yes']
Is the worker separated from the emission source(s) by means of a personal enclosure around the worker (e.g. cabin)?
Answer:
Dropdown list with following possibilities:

- Partial personal enclosure without ventilation
- Partial personal enclosure with ventilation
- Complete personal enclosure without ventilation
- Complete personal enclosure with ventilation
- No personal enclosure

Descriptions and assigned values of each category are given in the table below:

Classification	Description	Assigned value

Partial personal enclosure without ventilation	Partial personal enclosure is a partially open cabin or room (e.g. open windows, door) where a worker is partially protected but still in direct contact with the work environment. The air within the personal enclosure is not actively ventilated.	0.7
Partial personal enclosure with ventilation	Partial personal enclosure is a partially open cabin or room (e.g. open windows, door) where a worker is partially protected but still in direct contact with the work environment. The air within the personal enclosure is ventilated and a positive pressure is maintained inside the personal enclosure.	0.3
Complete personal enclosure without ventilation	Worker resides inside an enclosed cabin or room (door & windows closed) for the entire duration of the activity. The air within the separate room is not actively ventilated.	0.3
Complete personal enclosure with ventilation	Worker resides inside an enclosed cabin or room (door and/or windows closed) for the entire duration of the activity. The air within the personal enclosure is actively ventilated and filtered and a positive pressure is maintained inside the personal enclosure.	0.1
No personal enclosure	No personal enclosure within a work environment	1

Guidance text:

Select the personal enclosure available to the worker then click Next to continue.
Personal enclosure is defined as providing a worker with a personal enclosure within a work environment, e.g. air-conditioned cabin. The concept of personal enclosure is similar to that of segregation, except that for personal enclosure not the source but the worker is placed in an enclosure within a work environment. The worker resides inside the personal enclosure for the entire duration of the activity. Personal enclosure only applies to sources in the far field.

4.8 Surface contamination / fugitive emission sources

Question 45:
Is the process fully enclosed and is the integrity of that enclosure regularly monitored?
Answer:
Dropdown list with following possibilities:

- Yes -> *assign value from table below and go to question 48*
- No

Question 46:
Are demonstrable and effective housekeeping practices in place (e.g. daily cleaning using appropriate methods (e.g. vacuum), preventive maintenance of machinery and control measures, and use of protective clothing that will repel spills and reduce personal cloud)?
Answer:
Dropdown list with following possibilities:

- Yes -> *assign value from table below and go to question 48*
- No

Question 47:
Are general housekeeping practices in place?
Answer:
Dropdown list with following possibilities:

- Yes
- No

Descriptions and assigned values of each category are given in the table below:

Scenario descriptor	**Modifying factor** **Low-volatile liquid aerosols (incl. powders dissolved in a liquid)**	**Modifying factor** **Solid aerosols and volatile liquids (vapours)**
Default level (no specific cleaning practices, no protective clothing that repel spills, process not fully enclosed)	0.01	0.01
General good housekeeping practices	0.003	0.003
Demonstrable and effective housekeeping practices (examples include daily cleaning using appropriate methods (eg vacuum), preventive maintenance of machinery and control measures, and use of protective clothing that will repel spills and reduce personal cloud)	0.001	0.001
Process fully enclosed (air tight) and the integrity of the enclosure is monitored at least once a month. The containment is not breached for example for sampling or routine cleaning.	0	0

Guidance text:

Emissions from contaminated surfaces arise from the evaporation of liquids or the re-suspension of dusts from leaks, spills or other sources that have produced surface contamination. Surfaces that may be contaminated include work surfaces, floors, walls, clothing, tools, process equipment, and used rags. Contamination may arise due to leaks or spills, or in the case of particles, deposition from the airborne state. Exposure from these sources will occur through re-suspension of settled dust or evaporation of spilled liquids.
Fugitive emissions are unintended and unpredictable leaks from process equipment that are not yet classified as a near-field or far-field source.

4.9 Dispersion (FF source)

Question 48:
Is the work performed indoors or outdoors?
Answer:
Dropdown list with following possibilities:

- Indoors -> *go to question on room size*

  - ***Question 49:*** What is the room size of the work area?
    - Any size workroom
    - Large workrooms only
    - Small workrooms only
    - 30 m^3
    - 100 m^3
    - 300 m^3
    - 1000 m^3
    - 3000 m^3
  - ***Question 50:*** What is the ventilation rate of the general ventilation system in the work area?
    - No restriction on general ventilation characteristics
    - Only good natural ventilation
    - Mechanical ventilation giving at least 1 ACH
    - Specialised room ventilation with more than 10 ACH
    - 0.3 air changes per hour (ACH)
    - 1 air changes per hour (ACH)
    - 3 air changes per hour (ACH)
    - 10 air changes per hour (ACH)
    - 30 air changes per hour (ACH)
- Outdoors (*clarifying text: "Only for situations where there are no or few boundaries nearby, i.e. the source is not located close to walls or in an enclosed courtyard. If this is not the case, the assessor should assume the work is essentially carried out indoors in an appropriately sized room.") -> go to separate dropdown list for outdoors*
  - ***Question 51***: Is the source located close to buildings?
    - Yes
    - No
  - ***Question 52:*** Is the worker located further than 4 meters from this far field source?
    - Yes
    - No

Dispersion category	**Description**
Indoors	Both the source and the worker are located indoors. The indoor environment should be enclosed by walls on each side and a roof on top. A garage with the garage door open should be treated as an indoor environment.
Outdoors	Both the source and the worker are located outdoors. It is assumed there are two situations outdoors where the scenario may be located: close to buildings or away from buildings or other obstructions.

Descriptions and assigned values of each category are given in the table below. Based on the answer to question 16 and the exposure form (dust, mist, vapour or fume), the correct multiplier should be selected from the tables below.

Indoor Far-Field Multipliers for broader room size categories (long-term; 8-hour tasks)

Room volume descriptor	**Modifiers for use in the ART model**
Any size workroom	Choose from all relevant cells between 30 and 3000 m^3, with equal probability

Large workrooms only	Choice from relevant cells 300 to 3000 m^3, with equal probability
Small workrooms only	Choice from relevant cells 30 to 100 m^3, with equal probability

Indoor Far-Field Multipliers for broader ventilation rate categories (long-term; 8-hour tasks)

Ventilation rate descriptor	**Modifiers for use in the ART model**
No restriction on general ventilation characteristics	Choose from all relevant cells 0.3 to 3 ACH with equal probability
Only good natural ventilation	Choice from all relevant cells 0.3, 1 and 3 ACH with weighting 20%, 40%, 40%
Mechanical ventilation giving at least 1 ACH	Choice from all relevant cells 1, 3, 10 and 30 ACH with weighting 55%, 25%, 15%, 5%
Specialised room ventilation with more than 10 ACH	Choice from all cells 10 to 30 ACH with equal probability

*Indoor Far-Field Multipliers for **vapours (volatile liquids) and gases** (long-term; 8-hour tasks)*

Room volume (m^3)	**0.3 ACH**	**1 ACH**	**3 ACH**	**10 ACH**	**30 ACH**
30	35	16	6.1	1.9	0.6
100	12	5	1.8	0.6	0.2
300	3.9	1.6	0.6	0.2	0.1
1000	1.2	0.5	0.2	0.06	0.02
3000	0.4	0.2	0.1	0.02	0.01

*Indoor Far-Field Multipliers for **dusts, mists (low-volatile liquids), powders in liquids, paste/slurry, solid objects and fibres** (long-term; 8-hour tasks)*

Room volume (m^3)	0.3 ACH	1 ACH	3 ACH	10 ACH	30 ACH
30	5.7	3.4	1.7	0.8	0.3
100	2.1	1.2	0.6	0.3	0.1
300	0.8	0.4	0.2	0.1	0.04
1000	0.2	0.1	0.1	0.03	0.01
3000	0.1	0.05	0.02	0.01	0.004

*Indoor Far-Field Multipliers for **fumes** (long-term; 8-hour tasks)*

Room volume (m^3)	0.3 ACH	1 ACH	3 ACH	10 ACH	30 ACH
30	28.5	14.0	5.6	1.8	0.6
100	9.6	4.4	1.7	0.5	0.2
300	3.4	1.5	0.6	0.2	0.1

1000	1.0	0.5	0.2	0.1	0.02
3000	0.3	0.2	0.1	0.02	0.01

Outdoor Multipliers for ***vapours (volatile liquids), gases and fumes***

	Close to buildings	Far from buildings
FF (1 – 4 m)	0.03	0.01
FF (> 4 m)	0.01	0.003

Outdoor Multipliers for ***dusts and mists (low-volatile liquids), powders in liquids, paste/slurry, solid objects and fibres***

	Close to buildings	Far from buildings
FF (1 – 4 m)	0.015	0.005
FF (> 4 m)	0.005	0.00167

Guidance text:

Dispersion is the movement of a contaminant from a source throughout the work area, giving rise to varying spatial concentrations. The dispersion is dependent on the size of the workroom and the air changes in this room (with personal exposure levels being higher in a small poorly ventilated room).

Note, if the room size or air change rate is between two categories, then the next lower category should be selected for a specific situation, e.g. a 200 m^3 room with 0.7 ACH should have the multiplier for 100 m^3 and 0.3 ACH selected.

[No further questions]

4.10 Activity emission potential (NF source)

Question 55:

To which activity class does your activity belong?

Answer:

Dropdown list with following possibilities:

[Based on the product type selected in question 3, the activity classes marked with a '+' in the table below should appear in the dropdown list.]

Activity class	**Description [given by mouse-over]**	**Applies for "solid objects"**	**Applies for Powdered, granular and pelletized material**	**Applies for liquids and powders dissolved in a liquid**	**Applies for paste, slurry or clearly wet powder**	**Applies for hot or molten metals**
Fracturing and abrasion of solid objects	Activities where solid objects are broken into smaller parts or are abraded due to frictional forces.	+	-	-	-	-
Abrasive blasting	A surface preparation technique for removing coatings or contamination by propelling abrasive material towards the surface at high velocity.	+	-	-	-	-

	ART only considers exposure arising from the surface coatings during abrasive blasting (i.e., exposure to the abrasive material is not included)					
Impaction on contaminated solid objects	Activities where impaction or striking of a tool on an object contaminated with powder or granules potentially results in re-suspension of that powder. For this activity class, exposure is estimated to be related to the level of contamination on the surface or the object that is impacted on.	-	+	-	-	-
Handling of contaminated solid objects or paste	Handling or transport of surfaces, objects or pastes that are (potentially) contaminated with powders or granules. For this activity class, exposure is estimated to the contamination on the surface, object or paste.	-	+	-	+	-
Spray application of powders	Spraying activities used to intentionally disperse powders on surfaces by using a pressure difference.	-	+	-	-	-
Movement and agitation of powders, granules or pelletized material	Activities where movement and agitation of powders results in disturbances of the product causing dust particles to become airborne.	-	+	-	-	-
Transfer of powders, granules or pelletized material	Activities where a stream of powder is transferred from one reservoir (or container, vessel) to the receiving vessel. The product may either fall due to gravity from a high to a lower point (dumping of powders), be transferred horizontally (scooping of powders) or is transferred through a hose or tube with pressure (vacuum transfer).	-	+	-	-	-
Compressing of powders, granules or pelletized material	Activities where powders, granules or pelletized material are compressed due to compaction or crushing.	-	+	-	-	-
Fracturing of powders, granules or pelletized material	Activities where powders, granules or pelletized material are crushed and broken into smaller parts or sizes due to frictional forces (e.g. between two surfaces or objects)	-	+	-	-	-
Spray application of liquids	Handling of a liquid product in a bath or other reservoir. The liquid may either be relatively undisturbed (e.g. manual stirring, dipping in bath) or agitated (e.g. gas bubbling, mechanical mixing in vessel).	-	-	+	-	-

Activities with open liquid surfaces or open reservoirs		-	-	+	-	-
Handling of contaminated objects	Handling of solid objects that are treated or contaminated with the liquid of interest.	-	-	+	-	-
Spreading of liquid products	Activities where a liquid product is directly spread on surfaces using e.g. a roller, brush or wipe.	-	-	+	-	-
Application of liquids in high speed processes		-	-	+	-	-
Transfer of liquid products		-	-	+	-	-
Burning of liquids [*This is outside the applicability domain of the beta version. Should be visible but not selectable*]		-	-	+	-	-
Smelting and melting of metal		-	-	-	-	+
Pouring or tapping of molten metal (including melt drossing and dipping in molten metal)		-	-	-	-	+
Sintering, roasting and oxidation / burning		-	-	-	-	+
Spray application of molten metal		-	-	-	-	+
Atomisation		-	-	-	-	+
Compressing of, impaction on, or hardening of hot metal objects		-	-	-	-	+

See table below for combination of activity classes and subclasses with example activities. Show the example activities with the dropdown lists above (mouse-over function).

Activity class	**Activity subclass**	**Example activities**
Fracturing and abrasion of solid objects		• Crushing concrete • Jack hammering • Pulverizing • Sawing using a circular saw • (Manual) milling • Sanding • (Cut-off) grinding of steel • Drilling • Buffing • Polishing • Chiselling • Cutting • Logging • Demolishing with wrecking ball • Wrecking • Shredding of batteries • Wire drawing • Cold rolling of metal sheets
Abrasive blasting		• Grit blasting • (Ultra) high pressure blasting for stripping paint • Water cutting
Impaction on contaminated solid objects		• Hammering • Nailing

		• Piling • Punching
Handling of contaminated solid objects or paste		• Sorting • Stacking • Carrying • Picking / collecting objects • Packaging • Paving • Wrapping • Disposal of empty bags • Plastering • Kneading • Modelling of product • Bending metal tubes
Spray application of powders		• Dusting crops • Powder coating • Spraying of concrete
Movement and agitation of powders, granules or pelletized material		• Sweeping • Application of compressed air • Vacuum cleaning • Mixing • Weighing • Raking • Sieving
Transfer of powders, granules or pelletized material	Falling of powders, granules or pelletized material	• Bagging solids • Dumping solids in mixers • Loading barges with minerals or cereals • Scooping • Scattering • Filling of bottles
	Vacuum transfer of powders, granules or pelletized material	• *[picture vacuum transfer]*
Compressing of powders, granules or pelletized material		• (steam)Rolling • Compacting • Tabletting • Granulation • Pelletization
Fracturing of powders, granules or pelletized material		• Grinding minerals • Milling cereals • Very small scale crushing • Testing tablets • De-lumping (breaking up products) • Large scale bulk milling
Spray application of liquids	Surface spraying of liquids	• Spray application of paints on e.g. ships (using HVLP or airless techniques) • Pest control operations (using backpack) • Spraying cleaning agents onto surfaces • Foaming • Tractor mounted spraying
	Spraying of liquids in a space	• Spraying room deodorizers or fragrances • Fogging • Fly spray
Activities with open liquid surfaces or open reservoirs	Activities with relatively undisturbed surfaces (no aerosol formation)	• Dipping objects in a cleaning bath (where the presence of treated surfaces in the area is limited) • Immersion of objects • Manual stirring of paint • Tank dipping
	Activities with agitated surfaces	• Electroplating • Bath with gas bubbling • Mechanical mixing / blending of paint • Aeration of waste water • Boiling • Shaking liquids (e.g. in chemical laboratories)
Handling of contaminated objects		• Heat drying tasks • Evaporation from painted surface or object • Maintenance of fuel pumps • Coupling and decoupling of hoses or (drilling) equipment

		• Handling of contaminated tools
Spreading of liquid products		• Painting a ceiling and walls with a roller and a brush • Hand lay-up activities with styrene • Pouring a liquid flooring material on a floor • Cleaning of liquid spills • Gluing • Mopping • Embalming • Laminating • Lubricating • Sponging • Screen printing • Cleaning of oil residue from bulk tanks
Application of liquids in high speed processes (e.g. rotating tools)		• Use of metal working fluids with e.g. circular saws and drills • Centrifuging wet items • Press printing
Transfer of liquid products	Bottom loading	• Bottom loading of tanker at bulk terminal • Under wing refuelling of aircraft • Transfer of additives in tanker using bottom loading
	Falling liquids	• Top loading of tanker at bulk terminal (boats, rail car or truck) • Filling of drums • Pouring • Filling of bottles • Filling of paint gun • Refuelling of cars • Manual calibration of fuel pump • Over wing refuelling of aircraft
Smelting and melting of metal	Smelting of metal	•
	Melting of metal	•
Pouring or tapping of molten metal (including melt drossing and dipping in molten metal)	Pouring or tapping of molten metal	•
	Dipping in molten metal	•
Sintering, roasting and oxidation / burning	Sintering	•
	Roasting	•
	Oxidation or burning	•
Spray application of molten metal		•
Atomisation		•
Compressing of, impaction on, or hardening of hot metal objects		• Quenching • Hot rolling • Metal cladding • Hot forging

Guidance text:

Use the left-hand panel to select the activity class that best fits this emission source.
In some cases an activity class has several subclasses. Use the drop-down list in the right-hand panel to narrow down your selection.
For each activity class/subclass you will be shown several activities typical for the selected class.

In the next paragraphs, each of the activity (sub)classes is further defined. Based on the choice in the dropdown list above go to the relevant section below.

4.10.1 Fracturing and abrasion of solid objects

Question 56:
Which of the situations below does best represent your activity?

Answer:

Dropdown list with following possibilities:

Wood

- Mechanical sanding of wood resulting in large amounts of dust
- Mechanical handling of wood resulting in large amounts of dust (e.g., large speed of moving work pieces or rotating cutting blades)
- Mechanical handling of wood resulting in limited amount of dust
- Manual handling of wood resulting in limited amount of dust
- Manual handling of wood resulting in very limited amount of dust

Stone

- Mechanical pulverization of large amounts of stone or large objects
- Mechanical treatment / abrasion of large surfaces
- Mechanical treatment / abrasion of small sized surfaces
- Mechanical pulverization of stones
- Manual pulverization or treatment / abrasion of small sized objects
- Careful breaking stones

Metal

- Mechanical abrasion or fracturing of metal resulting in small amount of dust
- Mechanical abrasion or fracturing of metal resulting in very limited amount of dust
- Mechanical deforming of metal

Classes and related exposure weights representing emission potential for fracturing and abrasion of wood.

Description	**Examples**	**Exposure weights**
Mechanical sanding of wood resulting in large amounts of dust	belt sanding, handheld sanding machine	30
Mechanical handling of wood resulting in large amounts of dust (e.g., large speed of moving work pieces or rotating cutting blades)	milling operations, lathe, circular saw	10
Mechanical handling of wood resulting in limited amount of dust	planer, chainsaw, shredder, drilling of holes	3
Manual handling of wood resulting in limited amount of dust	manual sawing or sanding, scraping of paint	3
Manual handling of wood resulting in very limited amount of dust	screw setting, manual planing	0.3

Classes and related exposure weights representing emission potential for fracturing and abrasion of stone.

Description	**Examples**	**Exposure weights**
Mechanical pulverization of large amounts of stone or large objects	Stone crushing machines, demolition using explosives, using a jack hammer to demolish large surfaces, demolition using a crane	100
Mechanical treatment / abrasion of large surfaces	surface grinding, smoothing of concrete walls and floors, cutting concrete blocks using masonry saw	100

Mechanical treatment / abrasion of small sized surfaces	using hand-held grinders to remove mortar	30
Mechanical pulverization of stones	using power tools like jack hammers to demolish small surfaces, recess millers	10
Manual pulverization or treatment / abrasion of small sized objects	use of non-powered tools like hammer or chisel, manual polishing	3
Careful breaking stones	mechanical tile breaking	0.3

Classes and related exposure weights representing emission potential for fracturing and abrasion of metal objects.

Description	**Examples**	**Exposure weights**
Mechanical abrasion or fracturing of metal resulting in small amount of dust	Sanding metal objects. grinding steel	3
Mechanical abrasion or fracturing of metal resulting in very limited amount of dust	shredding of batteries, sawing or slitting of metal objects,	1
Mechanical deforming of metal	rolling metal sheets	0.1

Question 56.6:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classes and related exposure weights representing emission potential for containment during fracturing and abrasion of wood.

Classification	**Examples**	**Assigned value**
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosed cover on a circular saw (relatively small openings are possible)	0.3

Classes and related exposure weights representing emission potential for containment during fracturing and abrasion of stone.

Classification	**Examples**	**Assigned value**
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosed stone crushing machine (relatively small openings are possible)	0.3

Classes and related exposure weights representing process containment during fracturing and abrasion of metal objects.

Classification	**Examples**	**Exposure weights**
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosed cover on a battery shredding process	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.
Select 'open process' here if the localized control 'containment without extraction' or 'glove boxes/bags' will be selected in the subsequent question on localized controls.

4.10.2 Abrasive blasting

Question 57:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Abrasive blasting of very large surfaces
- Abrasive blasting of large surfaces
- Abrasive blasting of small parts
- Micro-abrasive blasting

Exposure weights for activity emission potential of Activity Class 'abrasive blasting'.

Description	**Example**	**Exposure weight**
Abrasive blasting of very large surfaces	Removing (anti-fouling) paint from ships or bridges. Abrasive blasting is powered by compressed air.	100
Abrasive blasting of large surfaces	Blasting of e.g. car bodies, trailer frames	30
Abrasive blasting of small parts	Blast cleaning of small statues, bicycle frame parts	10
Micro-abrasive blasting	Small-scale dry abrasive blasting process in e.g. medical aids (blasting area of about a few cm).	1

Question 57.3:
What is the type of abrasive blasting technique?
Answer:

- Dry abrasive blasting
- Wet abrasive blasting

Exposure weights for the type of abrasive blasting technique.

Description	Example	Exposure weight
Dry abrasive blasting	Abrasive blasting is powered by compressed air.	1
Wet abrasive blasting	Includes systems where a mixture of abrasive and water is propelled by compressed air, where water is added to abrasive blasting nozzle, or water jet stripping systems.	0.3

Question 57.5:
What is the direction of abrasive blasting?
Answer:

- Abrasive blasting in any direction (including upwards)
- Only horizontal or downward blasting
- Only downward blasting

Exposure weights for abrasive blasting during the activity emission potential of Activity Class 'abrasive blasting'.

Description	Exposure weight
Abrasive blasting in any direction (including upwards)	3
Only horizontal and downward blasting	1
Only downward blasting	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
For this activity class, exposure is estimated to the solid material (or any liquid in or on the surface of the solid matrix) that is being abraded.
The categories are in rank order with activities generating highest emission levels at the top.

4.10.3 Impaction on contaminated solid objects

Question 58:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Impaction on substantially and visibly contaminated objects (layers of more than 0.5 kg).
- Impaction on objects with visible residual dust
- Impaction on objects with limited visible residual dust
- Impaction on slightly contaminated (layers of less than few grams) objects
- Impaction on apparently clean objects

Classes and related exposure weights for activity emission potential of Activity Class 'Impaction on contaminated solid object'

Description	**Examples**	**Exposure weight**
Impaction on substantially and visibly contaminated objects (layers of more than 0.5 kg).	Impaction on heavily contaminated filters	3
Impaction on objects with visible residual dust	Hammering on contaminated objects	1
Impaction on objects with limited visible residual dust	Impaction on limited contaminated drums or transfer line.	0.3
Impaction on slightly contaminated objects (layers of less than few grams)	Impaction on objects after closed filling operations.	0.1
Impaction on apparently clean objects	Impaction on drums coming out of a cleaning machine	0.001

Question 58.5:
What is the type of handling?
Answer:
Dropdown list with following possibilities:

- Heavy mechanical impaction
- Normal impaction (manual or light mechanical)

Classes and related exposure weights for type of handling for activity emission potential of Activity Class 'Impaction on contaminated solid object'

Description	**Examples**	**Exposure weight**
Heavy mechanical impaction	Hydraulic hammers.	3
Normal impaction (manual or light mechanical)	Manual hammering, beating carpets	1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
For this activity class, exposure is estimated to the contamination on the surface or object that is impacted upon.
The categories are in rank order with activities generating highest emission levels at the top.

4.10.4 Handling of contaminated solid objects or paste

Question 59:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Handling of substantially and visibly contaminated objects (layers of more than 0.5 kg).
- Handling of objects with visible contamination (object covered with fugitive dust from surrounding dusty activities)
- Handling of objects with limited residual dust (thin layer visible)
- Handling of slightly contaminated (layers of less than few grams) objects
- Handling of apparently clean objects

Classes and related exposure weights for activity emission potential of activity subclass ‘Handling of contaminated solid objects or pastes’

Description	Examples	Exposure weight
Handling of substantially and visibly contaminated objects (layers of more than 0.5 kg).	Stacking cement bags with dust contamination (leakage from bag valve), disposal of empty contaminated bags, disposal of heavily contaminated filters, maintenance of heavily contaminated equipment	1
Handling of objects with visible contamination (object covered with fugitive dust from surrounding dusty activities)	Transport of contaminated wooden objects Carrying contaminated bags, changing contaminated filters	0.3
Handling of objects with limited residual dust (thin layer visible)	Transportation of drums. Coupling/decoupling of transfer line. Transport of contaminated metal objects. Replacing filters.	0.1
Handling of slightly contaminated objects (layers of less than few grams product)	Handling of slightly contaminated glass bottles or plastic kegs. Packaging of objects after closed filling operations.	0.03
Handling of apparently clean objects	Drums coming out of a cleaning machine	0.001

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
For this activity class, exposure is estimated to the contamination on the surface or object.
The categories are in rank order with activities generating highest emission levels at the top.

Question 59.5:
How are contaminated objects or pastes handled?
Answer:
Dropdown list with following possibilities:

- Handling that departs from regular work procedures and involves large amounts of energy
- Normal handling, involves regular work procedures.
- Careful handling, involves workers showing attention to potential danger, error or harm and carrying out the activity in a very exact and thorough (or cautious) manner.

Classes and related exposure weights for type of handling.

Description	Exposure weight
Handling that departs from regular work procedures and involves large amounts of energy (e.g. rough handling or throwing of bags)	3
Normal handling, involves regular work procedures.	1

Careful handling, involves workers showing attention to potential danger, error or harm and carrying out the activity in a very exact and thorough (or cautious) manner.	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.10.5 Spray application of powders

Question 60:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Powder coating
- Dusting using blower

Classes and related exposure weights for activity emission potential of Activity Class 'spray application of powders'.

Description	**Example**	**Exposure weights**
Powder coating	Powder spraying using electrostatic spray gun	10
Dusting using blower	Dusting crops with knapsack dust blower	3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Question 60.5:
What is the spray direction?
Answer:

- Spraying in any direction (including upwards)
- Only horizontal or downward spraying
- Only downward spraying

Classes and related exposure weights for spray direction.

Description	**Exposure weights**
Spraying in any direction (including upwards)	3
Only horizontal or downward spraying	1
Only downward spraying	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.

The categories are in rank order with activities generating highest emission levels at the top.

4.10.6 Movement and agitation of powders, granules or pelletized material

Question 61:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Movement and agitation of 1000 kg or more
- Movement and agitation of 100 - 1000 kg
- Movement and agitation of 10 - 100 kg
- Movement and agitation of 1 - 10 kg
- Movement and agitation of 0.1 - 1 kg
- Movement and agitation of 10 - 100 gram
- Movement and agitation of < 10 gram

Classes and related exposure weights for activity emission potential of Activity Class 'movement and agitation of powders, granules or pelletized material)'

Description	**Example activities**	**Exposure weight**
Movement and agitation of 1000 kg or more	Sieving big bag volumes in large production plants (e.g. sieving peat moss)	30
Movement and agitation of 100 - 1000 kg	Cleaning large heaps of dust or debris (after demolition) Sieving, mixing or blending in vessels	10
Movement and agitation of 10 - 100 kg	Cleaning heavily contaminated floors (e.g. after dusty activities like bagging or abrasion) Sieving, mixing or blending in large buckets	3
Movement and agitation of 1 - 10 kg	Cleaning floors (sweeping) covered with fugitive dust Manual sieving, mixing or blending	1
Movement and agitation of 0.1 - 1 kg	Using brush and dustpan to clean up small spills Manual sieving, mixing or blending	0.3
Movement and agitation of 10 - 100 gram	Using brush and dustpan to clean up small spills Manual sieving, mixing or blending	0.1
Movement and agitation of < 10 gram	Cleaning valves/machinery/equipment with wipe Mixing on laboratory scale	0.03

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Question 61.5:
What is the handling type?
Answer:

Dropdown list with following possibilities:

- Application of compressed air
- Other handling with high level of agitation
- Handling with low level of agitation

Classes and related exposure weights for type of handling

Description	Examples	Exposure weight
Application of compressed air	Using compressed air to clean e.g. machines	30
Other handling with high level of agitation	Sweeping of floors, sieving, mechanical mixing	3
Handling with low level of agitation	Manual mixing	1

Question 61.7:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	Examples	Exposure weight
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Contained sieving of big bags with only small opening	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.
Select 'open process' here if the localized control 'containment without extraction' or 'glove boxes/bags' will be selected in the subsequent question on localized controls.

4.10.7 Transfer of powders, granules or pelletized material

4.10.7.1 Falling powders

Question 62:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Transferring more than 1000 kg/minute
- Transferring 100 – 1000 kg/minute
- Transferring 10 – 100 kg/minute

- Transferring 1 – 10 kg/minute
- Transferring 0.1 – 1 kg/minute
- Transferring 10 – 100 gram/minute
- Transferring less than 10 gram/minute

Classes and related exposure weights for activity emission potential of Activity Class ‘Falling of powdered, granular or pelletized material’.

Description	**Examples**	**Exposure weights**
Transferring more than 1000 kg/minute	Large scale transfer with big bags	30
Transferring 100 – 1000 kg/minute	Automated dumping of powders (e.g. auger or conveyer belt)	10
Transferring 10 – 100 kg/minute	Manual dumping of powders	3
Transferring 1 – 10 kg/minute	Scooping activities	1
Transferring 0.1 – 1 kg/minute	Filling bottles	0.3
Transferring 10 – 100 gram/minute	Small-scale scooping for sampling	0.1
Transferring less than 10 gram/minute	Very small scale weighing (fine adjustments) and scooping in laboratory	0.03

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Question 62.5:

What is the type of handling?

Answer:

Dropdown list with following possibilities:

- Routine transfer
- Careful transfer involves workers showing attention to potential danger, error or harm and carrying out the activity in a very exact and thorough (or cautious) manner, e.g. careful weighing in laboratory.

Exposure weights for type of handling

Description	**Exposure weight**
Routine transfer	1
Careful transfer involves workers showing attention to potential danger, error or harm and carrying out the activity in a very exact and thorough (or cautious) manner. e.g. careful weighing in laboratory	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.

The categories are in rank order with activities generating highest emission levels at the top.

Question 62.7:
What is the drop height?
Answer:
Dropdown list with following possibilities:

- Drop height > 0.5 m
- Drop height < 0.5 m

Exposure weights for drop height

Description	**Exposure weight**
Drop height > 0.5 m	3
Drop height < 0.5 or transfer using a pipe	1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The drop height is measured from the bottom of the dumping opening to the top of the receiving object or surface.

Question 62.8:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	**Examples**	**Exposure weight**
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Dumping powders in a big bag through a small dumping opening	0.3

4.10.7.2 Vacuum transfer of powders

Question 62.9.1:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Transferring more than 1000 kg/minute
- Transferring 100 – 1000 kg/minute
- Transferring 10 – 100 kg/minute
- Transferring 1 – 10 kg/minute
- Transferring 0.1 – 1 kg/minute
- Transferring 10 – 100 gram/minute
- Transferring less than 10 gram/minute

Classes and related exposure weights for activity emission potential of sub Activity Class 'Vacuum transfer of powders'.

Description	Examples	Exposure weights
Transferring more than 1000 kg/minute	Large scale vacuum transfer from large vessels	3
Transferring 100 – 1000 kg/minute		1
Transferring 10 – 100 kg/minute		0.3
Transferring 1 – 10 kg/minute		0.1
Transferring 0.1 – 1 kg/minute		0.03
Transferring 10 – 100 gram/minute		0.01
Transferring less than 10 gram/minute	Micro powder transfer systems	0.003

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Question 62.9.2:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classes and related exposure weights representing process containment during vacuum transfer of powders, granules or pelletized material

Classification	Examples	Exposure weights
Open process	Vacuum transfer from open reservoir to enclosed reservoir	1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Vacuum transfer from reservoir with small opening to enclosed reservoir	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.
Select 'open process' here if the localized control 'containment without extraction' or 'glove boxes/bags' will be selected in the subsequent question on localized controls.

4.10.8 Compressing of powders, granules or pelletized material

Question 63:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Compressing more than 1000 kg/minute
- Compressing 100 – 1000 kg/minute
- Compressing 10 – 100 kg/minute
- Compressing 1 – 10 kg/minute
- Compressing 0.1 – 1 kg/minute
- Compressing 10 – 100 gram/minute
- Compressing less than 10 gram/minute

Classes and related exposure weights for activity emission potential of Activity Class 'Compressing of powders, granules or pelletized material'

Description	Examples	Exposure weights
Compressing more than 1000 kg/minute	Large scale bulk compression of soil or wood pellets	30
Compressing 100 – 1000 kg/minute		10
Compressing 10 – 100 kg/minute		3
Compressing 1 – 10 kg/minute		1
Compressing 0.1 – 1 kg/minute		0.3
Compressing 10 – 100 gram/minute		0.1
Compressing less than 10 gram/minute	Very small scale tabletting, granulation	0.03

Question 63.3:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	Examples	Exposure weight
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosed tabletting machine (relatively small openings are possible)	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.

The categories are in rank order with activities generating highest emission levels at the top. Select 'open process' here if the localized control 'containment without extraction' or 'glove boxes/bags' will be selected in the subsequent question on localized controls.

4.10.9 Fracturing of powders, granules or pelletized material

[Note: when this activity class is selected, the dustiness category (Question 5) should be overruled and set to 'fine dust' (assigned value = 0.3)]

Question 63.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Fracturing more than 1000 kg/minute
- Fracturing 100 – 1000 kg/minute
- Fracturing 10 – 100 kg/minute
- Fracturing 1 – 10 kg/minute
- Fracturing 0.1 – 1 kg/minute
- Fracturing 10 – 100 gram/minute
- Fracturing less than 10 gram/minute

Description	**Examples**	**Exposure weights**
Fracturing more than 1000 kg/minute	Large scale bulk milling	30
Fracturing 100 – 1000 kg/minute		10
Fracturing 10 – 100 kg/minute		3
Fracturing 1 – 10 kg/minute		1
Fracturing 0.1 – 1 kg/minute		0.3
Fracturing 10 – 100 gram/minute		0.1
Fracturing less than 10 gram/minute	Very small scale crushing / testing tablets, de-lumping (breaking up products)	0.03

Question 63.8:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	**Examples**	**Exposure weight**
Open process		1.0
Handling that reduces contact between product and adjacent air.	Enclosed tablet crushing (relatively small openings are possible)	0.3

Note: This does not include processes that are fully contained by localized controls (see next questions).

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.
Select 'open process' here if the localized control 'containment without extraction' or 'glove boxes/bags' will be selected in the subsequent question on localized controls.

4.10.10 Spray application of liquids

4.10.10.1 Surface spraying of liquids

Question 64:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- High application rate (> 3 l/minute)
- Moderate application rate (0.3 - 3 l/minute)
- Low application rate (0.03 – 0.3 l/minute)
- Very low application rate (< 0.03 l/minute)

Classes and related exposure weights for activity emission potential of Activity Subclass 'surface spraying of liquids'.

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
High application rate (> 3 l/minute)	Tractor mounted spraying	3	3
Moderate application rate (0.3 - 3 l/minute)	Paint spraying of e.g. ships	1	1
Low application rate (0.03 – 0.3 l/minute)	Pest control operations	0.3	0.3
Very low application rate (< 0.03 l/minute)	Spot spraying using e.g. controlled droplet application	0.1	0.1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
This activity class includes the spraying of liquids onto surfaces or objects (e.g. paint spraying).
The categories are in rank order with activities generating highest emission levels at the top.

Question 64.5:

What is the spray direction?
Answer:

- Spraying in any direction (including upwards)
- Only horizontal or downward spraying
- Only downward spraying

Classes and related exposure weights for spray direction.

Description	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Spraying in any direction (including upwards)	3	3
Only horizontal or downward spraying	1	1
Only downward spraying	0.3	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Question 64.7:
What is the spray technique?
Answer:

- Spraying with high compressed air use
- Spraying with no or low compressed air use

Classes and exposure weights for spray technique

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Spraying with high compressed air use	Air blast pesticide spraying of e.g. tree nursery	3	3
Spraying with no or low compressed air use	Paint spraying using HVLP or airless techniques; pest control operations using backpack	1	1

4.10.10.2 Spraying of liquids in a space

Question 65:
Which of the situations below does best represent your activity?

Answer:
Dropdown list with following possibilities:
- Large scale space spraying
- Small scale space spraying

Classes and related exposure weights for spraying of liquids in a space.

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weight**
Large scale space spraying	Fogging	30	30
Small scale space spraying	Fly spray	3	3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
This activity class includes the spraying of liquids into an open space (e.g. fogging or fly spray).
The categories are in rank order with activities generating highest emission levels at the top.

4.10.11 Activities with open liquid surfaces and open reservoirs

4.10.11.1 Activities with relatively undisturbed surfaces (no aerosol formation)

Question 66:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:
- Open surface > 3 m^2
- Open surface 1 - 3 m^2
- Open surface 0.3 - 1 m^2
- Open surface 0.1 – 0.3 m^2
- Open surface < 0.1 m^2

Classes and related exposure weights for activity emission potential of Activity Subclass ‘Activities with (evaporating) bath’

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Open surface > 3 m^2	Tank dipping	0.001	0.3

Open surface 1 - 3 m^2		0.001	0.1
Open surface 0.3 - 1 m^2		0.001	0.03
Open surface 0.1 – 0.3 m^2		0.001	0.01
Open surface < 0.1 m^2	Manual stirring in paint can Storage of laboratory samples	0.001	0.003

4.10.11.2 Activities with agitated surfaces

Question 66.3:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Open surface > 3 m^2
- Open surface 1 - 3 m^2
- Open surface 0.3 - 1 m^2
- Open surface 0.1 – 0.3 m^2
- Open surface < 0.1 m^2

Classes and related exposure weights for surface area

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Open surface > 3 m^2	Bath with gas bubbling (e.g. electroplating) Bath with ultrasonic cleaning	0.3	1.0
Open surface 1 - 3 m^2		0.1	0.3
Open surface 0.3 - 1 m^2		0.03	0.1
Open surface 0.1 – 0.3 m^2		0.01	0.03
Open surface < 0.1 m^2	Mechanical mixing in paint can, mechanical mixing very small amounts in e.g. laboratory	0.003	0.01

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.10.11.3 Handling of contaminated objects

Question 66.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Activities with treated/contaminated objects (surface > 3 m2)
- Activities with treated/contaminated objects (surface 1-3 m2)
- Activities with treated/contaminated objects (surface 0.3-1 m2)
- Activities with treated/contaminated objects (surface 0.1-0.3 m2)
- Activities with treated/contaminated objects (surface <0.1 m2)

Classes and related exposure weights for activity emission potential of Activity Subclass 'handling of contaminated objects'

Description		**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Activities with treated/contaminated objects (surface > 3 m^2)	Handling large treated and drying objects	0.001	0.3
Activities with treated/contaminated objects (surface 1-3 m^2)	Maintenance of fuel pumps; coupling and decoupling of hoses or (drilling) equipment	0.001	0.1
Activities with treated/contaminated objects (surface 0.3-1 m^2)	Handling small treated and drying objects	0.001	0.03
Activities with treated/contaminated objects (surface 0.1-0.3 m^2)	Handling of contaminated tools	0.001	0.01
Activities with treated/contaminated objects (surface <0.1 m^2)	Handling small tools in laboratory (e.g. pipettes)	0.001	0.003

Question 66.7:
What is the level of contamination of the surface of the objects?
Answer:
Dropdown list with following possibilities:

- Contamination > 90 % of surface
- Contamination 10-90 % of surface
- Contamination < 10 % surface

Classes and related exposure weights for level of contamination of objects

Description	**Aerosol exposure weights (incl. powders**	**Vapour exposure weights**

	dissolved in a liquid)	
Contamination > 90 % of surface	1	1
Contamination 10-90 % of surface	0.3	0.3
Contamination < 10 % surface	0.1	0.1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.10.11.4 Spreading of liquid products

Question 67:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Spreading of liquids at surfaces or work pieces > 3 m2 / hour
- Spreading of liquids at surfaces or work pieces 1.0 - 3.0 m2 / hour
- Spreading of liquids at surfaces or work pieces 0.3 - 1.0 m2 / hour
- Spreading of liquids at surfaces or work pieces 0.1 - 0.3 m2 / hour
- Spreading of liquids at surfaces or work pieces < 0.1 m2 / hour

Classes and related exposure weights for activity emission potential of Activity Subclass ‘Spreading of liquid products’

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Spreading of liquids at surfaces or work pieces > 3 m^2 / hour	Painting of walls or ships, removing (large) graffiti, cleaning of oil residue from bulk tanks	0.1	0.3
Spreading of liquids at surfaces or work pieces 1.0 - 3.0 m^2 / hour	Degreasing machines, painting of walls	0.1	0.1
Spreading of liquids at surfaces or work pieces 0.3 - 1.0 m^2 / hour	Painting of casings using a roller or brush, gluing e.g. shoe soles, degreasing or cleaning small machines/tools	0.1	0.03
Spreading of liquids at surfaces or work pieces 0.1 - 0.3 m^2 / hour	Spot degreasing (small objects like knifes), gluing stickers and labels	0.01	0.01
Spreading of liquids at surfaces or work pieces < 0.1 m^2 / hour	Small scale spreading e.g. in laboratory	0.001	0.003

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.10.12 Application of liquids in high speed processes (e.g. rotating tools)

Question 68:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large-scale activities involving high speed movements
- Small-scale activities involving high speed movements

Classes and related exposure weights representing emission potential for high speed processes.

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weight**
Large-scale activities involving high speed movements	Rotating pipes in oil drilling, rotating press during printing, application of metal working fluids in machining large work pieces	3	3
Small-scale activities involving high speed movements	Application of MWF in machining of small scale work pieces (e.g. < 10 kg)	1	1

Question 68.5:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process: no separation between process and worker
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	**Examples**	**Exposure weight**
Open process: no separation between process and worker		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosing panels around machining process	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Select 'open process' here if the localized control 'containment without extraction' or 'glove boxes/bags' will be selected in the subsequent question on localized controls.

4.10.13 Transfer of liquid products

4.10.13.1 Bottom loading

Question 70:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Transfer of liquid product with flow of > 1000 l/minute
- Transfer of liquid product with flow of 100 - 1000 l/minute
- Transfer of liquid product with flow of 10 - 100 l/minute
- Transfer of liquid product with flow of 1 - 10 l/minute
- Transfer of liquid product with flow of 0.1 - 1 l/minute
- Transfer of liquid product with flow of < 0.1 l/minute

Classes and related exposure weights for activity emission potential of Activity Class 'falling liquids'.

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Transfer of liquid product with flow of > 1000 l/minute	Loading of tanker at bulk terminal (boats, rail car or truck)	0.001	0.1
Transfer of liquid product with flow of 100 - 1000 l/minute	Loading of aircraft (under wing)	0.001	0.03
Transfer of liquid product with flow of 10 - 100 l/minute	Transfer of additives in tanker	0.001	0.01
Transfer of liquid product with flow of 1 - 10 l/minute	Transfer of additives in tanker	0.001	0.003
Transfer of liquid product with flow of 0.1 - 1 l/minute	Transfer of additives in tanker	0.001	0.001
Transfer of liquid product with flow of < 0.1 l/minute	Transfer of additives in tanker	0.001	0.001

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.10.13.2 Falling liquids

Question 71:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Transfer of liquid product with flow of > 1000 l/minute
- Transfer of liquid product with flow of 100 - 1000 l/minute
- Transfer of liquid product with flow of 10 - 100 l/minute
- Transfer of liquid product with flow of 1 - 10 l/minute
- Transfer of liquid product with flow of 0.1 – 1 l/minute
- Transfer of liquid product with flow of < 0.1 l/minute

Exposure weights for activity emission potential of Activity Class 'falling liquids' in case of splash loading.

Description		**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Transfer of liquid product with flow of > 1000 l/minute	Loading of tanker at bulk terminal (boats, rail car or truck)	0.1	0.1
Transfer of liquid product with flow of 100 - 1000 l/minute	Filling of drums	0.03	0.03
Transfer of liquid product with flow of 10 - 100 l/minute	(Re)fuelling cars, manual topping up, manual calibration of fuel pump	0.01	0.01
Transfer of liquid product with flow of 1 - 10 l/minute	Filling of bottles, filling of paint gun	0.003	0.003
Transfer of liquid product with flow of 0.1 – 1 l/minute	Filling of bottles, filling of paint gun	0.001	0.001
Transfer of liquid product with flow of < 0.1 l/minute	Transfer of small amounts in laboratory	0.001	0.001

Question 71.5:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	**Examples**	**Exposure weight**
Open process		1.0
Handling that reduces contact between product and adjacent air.	Transfer of liquid through a small filling opening (e.g. refuelling of	0.3

Note: This does not include processes that are fully contained by localized controls (see next questions).	vehicles)

Question 72:
Is the transfer of liquid performed by splash or submerged loading?
Answer:
Dropdown list with following possibilities:

- Splash loading, where the liquid dispenser remains at the top of the reservoir and the liquid splashes freely
- Submerged loading, where the liquid dispenser remains below the fluid level reducing the amount of aerosol formation

Classes and related exposure weights representing submerged and splash loading.

Classification	**Exposure weights**
Splash loading, where the liquid dispenser remains at the top of the reservoir and the liquid splashes freely	3.0
Submerged loading, where the liquid dispenser remains below the fluid level reducing the amount of aerosol formation	1.0

Guidance text:

Use the left-hand panel to select the situation that best fits this activity. The categories are in rank order with activities generating highest emission levels at the top.

4.10.14 Smelting or melting of metal

4.10.14.1 Smelting of metal

Question 73:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Smelting in an inherently closed process)

The actual smelting process has to be fully enclosed, including the loading/charging operation, and operators spend most of their time in control rooms during routine operation. This means that exposures are possible only during regular control inspections and tapping, which are part of activity class: “Pouring or tapping of molten metals”.

Classification	**Examples**	**Exposure weight**
Smelting in an inherently closed process		0.001

[If this activity subclass is selected, the answer to the localized control question cannot be ‘containment – no extraction’, ‘enclosing hoods’ or ‘glove boxes/bags’.]

Guidance text:

Use the left-hand panel to select the situation that best fits this activity. The categories are in rank order with activities generating highest emission levels at the top.

4.10.14.2 Melting of metal

Question 73.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large scale melting (> 10 tonnes)
- Medium scale melting (1-10 tonnes)
- Small scale melting (100 – 1000 kg)
- Very small scale melting (< 100 kg)

Classification	**Examples**	**Exposure weight**
Large scale melting (> 10 tonnes)	> 10 tonnes	3
Medium scale melting (1-10 tonnes)	1-10 tonnes	1
Small scale melting (100 – 1000 kg)	100 – 1000 kg	0.3
Very small scale melting (< 100 kg)	< 100 kg	0.1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.10.15 Pouring or tapping of molten metal (including melt drossing and dipping in molten metal)

4.10.15.1 Pouring or tapping of molten metal

Question 74:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large scale pouring or tapping (> 10 tonnes)
- Medium scale pouring or tapping (1-10 tonnes)
- Small scale pouring or tapping (100 – 1000 kg)
- Very small scale pouring or tapping (< 100 kg)

Classification	**Examples**	**Exposure weight**
Large scale pouring or tapping (> 10 tonnes)	> 10 tonnes	10
Medium scale pouring or tapping (1-10 tonnes)	1-10 tonnes	3
Small scale pouring or tapping (100 – 1000 kg)	100 – 1000 kg	1
Very small scale pouring or tapping (< 100 kg)	< 100 kg	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.

The categories are in rank order with activities generating highest emission levels at the top.

4.10.15.2 Dipping in molten metal

Question 74.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Open surface > 3 m2
- Open surface 1 - 3 m2
- Open surface 0.3 - 1 m2
- Open surface 0.1 – 0.3 m2
- Open surface < 0.1 m2

Classification	**Examples**	**Exposure weight**
Open surface > 3 m^2		3
Open surface 1 - 3 m^2		1
Open surface 0.3 - 1 m^2		0.3
Open surface 0.1 – 0.3 m^2		0.1
Open surface < 0.1 m^2		0.03

Question 74.7:
Is a flux used as a protective layer on the molten metal?
Answer:
Dropdown list with following possibilities:

- No use of flux
- Use of flux as protective layer on molten metal

Classification	**Examples**	**Exposure weight**
No use of flux		1
Use of flux as protective layer on molten metal	Fluxed bath	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.10.16 Sintering, roasting, oxidation or burning

4.10.16.1 Sintering

Question 75:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large scale sintering (> 10 tonnes)

- Medium scale sintering (1-10 tonnes)
- Small scale sintering (100 – 1000 kg)
- Very small scale sintering (< 100 kg)

Classification	Examples	Exposure weight
Large scale sintering (> 10 tonnes)	> 10 tonnes	10
Medium scale sintering (1-10 tonnes)	1-10 tonnes	3
Small scale sintering (100 – 1000 kg)	100 – 1000 kg	1
Very small scale sintering (< 100 kg)	< 100 kg	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.10.16.2 Roasting

Question 75.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large scale roasting (> 10 tonnes)
- Medium scale roasting (1-10 tonnes)
- Small scale roasting (100 – 1000 kg)
- Very small scale roasting (< 100 kg)

Classification	Examples	Exposure weight
Large scale roasting (> 10 tonnes)	> 10 tonnes	10
Medium scale roasting (1-10 tonnes)	1-10 tonnes	3
Small scale roasting (100 – 1000 kg)	100 – 1000 kg	1
Very small scale roasting (< 100 kg)	< 100 kg	0.3

Question 75.7:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Tunnel oven
- Enclosed roasting furnace

Classification	Examples	Exposure weight
Tunnel oven	Tunnel oven,	1
Enclosed roasting furnace	Rotary kiln	0.001

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.10.16.3 Oxidation, burning

Question 76:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large scale oxidation, burning (> 10 tonnes)
- Medium scale oxidation, burning (1-10 tonnes)
- Small scale oxidation, burning (100 – 1000 kg)
- Very small scale oxidation, burning (< 100 kg)

Classification	Examples	Exposure weight
Large scale oxidation, burning (> 10 tonnes)		10
Medium scale oxidation, burning (1-10 tonnes)	Production of speciality products, such as high purity oxides	3
Small scale oxidation, burning (100 – 1000 kg)		1
Very small scale oxidation, burning (< 100 kg)	Rotary furnaces	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.10.17 Spray application of hot metal

Question 76.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Deposition rate > 5 kg/hr
- Deposition rate < 5 kg/hr

Classification	Examples	Exposure weight
Deposition rate > 5 kg/hr	Detonation gun	0.03
Deposition rate < 5 kg/hr	Plasma spraying	0.01

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.10.18 Atomisation

Question 77:

[There is no question needed here. This is just one class. When this sub activity class is selected, show the following text:
Metallic powders can be obtained by atomisation of a furnace melt (melt atomisation). This can be achieved by a variety of means such as by spraying molten metal under pressure through a nozzle into a variety of media {liquid atomisation (water or oil) or gas atomisation (air, nitrogen or argon) techniques} and by more specialised techniques including centrifugal atomisation {pouring a melt onto a rotating disc or using the Rotating Electrode Process (REP)}, ultrasound and pressure. This process requires full enclosure to achieve atomisation and powder formation.

Classification	**Examples**	**Exposure weight**
Atomisation in enclosed tank		0.001

[If this activity subclass is selected, the answer to the localized control question cannot be 'containment – no extraction', 'enclosing hoods' or 'glove boxes/bags'.]

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.10.19 Compressing of, impacting on, or hardening of metal objects

Question 78:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Mechanical hot forging, hot rolling or quenching of large scale metal objects
- Manual forging, small scale mechanical rolling or quenching of smaller sized hot metal objects

Classification	**Examples**	**Exposure weight**
Mechanical hot forging, hot rolling or quenching of large scale metal objects	Hot rolling of slabs > 5000 kg Hot forging of metal objects that cannot be lifted by hand (> 50 kg)	10
Manual forging, small scale mechanical rolling or quenching of smaller sized hot metal objects	Quenching knives or swords Manual forging (e.g. horse smith using hammer and anvil) Hot rolling of rods < 5000 kg	1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.11 Localized controls (NF source)

Question 80:
Are there any control measures in close proximity of the far field emission source intended to minimize emissions from the source? *[Warning text: "the control measure should cover the whole activity"].*

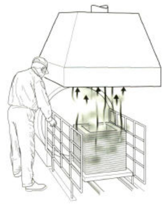
Answer:
Dropdown list with following possibilities:

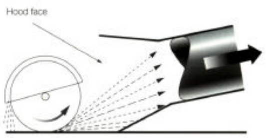
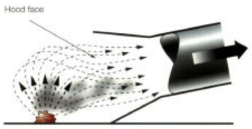
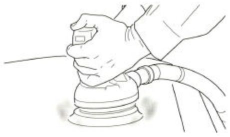
- No localized controls -> go to question 81
- Suppression techniques *[This class should only be visible if the answer to question 3 = "*Powdered, granular or pelletized material" or "Solid objects"] -> *go to separate dropdown list for suppression techniques below*
    - Knockdown suppression
    - Wetting at the point of release
- Containment – no extraction *[If this class is selected the answer to the containment question in the activity emission potential should be overruled and set to 'open process']*
    - Low level containment
    - Medium level containment
    - High level containment
- Local exhaust ventilation (LEV) -> *go to separate dropdown list for LEV below*
    - Receiving hoods -> *go to separate dropdown list for receiving hoods below*
        - Canopy hood
        - Other receiving hoods
    - Capturing hoods -> *go to separate dropdown list for capturing hoods below*
        - Movable capturing hood
        - Fixed capturing hood
        - On-tool extraction
    - Enclosing hoods -> *go to separate dropdown list for enclosing hoods below.*
        - Fume cupboard
        - Horizontal/downward laminar flow booth
        - Other enclosing hoods
    - Other LEV systems
- Glove boxes and glove bags *[If this class is selected the answer to the containment question in the activity emission potential should be overruled and set to 'open process']*
        - Glove bags
            - Glove bags (non-ventilated)
            - Glove bags (ventilated or kept under negative pressure)
        - Glove boxes
            - Low specification glove box
            - Medium specification glove box
            - High specification glove box / isolator
- Vapour recovery systems

Descriptions and assigned values of each category are given in the table below.

Classification	Description	Assigned typical value	Guidance images
No localized controls	No control measures in close proximity of the source.	1	
Suppression techniques			
Knockdown suppression *[This class should only be visible if the answer to question 3 =*	Post generation suppression of airborne contaminants to reduce dust levels. Knockdown of a contaminant after it has been emitted.	0.7	

“Powdered, granular or pelletized material” or “Solid objects”]			
Wetting at the point of release *[This class should only be visible if the answer to question 3 =* “Powdered, granular or pelletized material” or “Solid objects”]	Wetting systems that wet the process at the point of release (focusing on the emission source) to agglomerate and bind the fine particles to prevent dust from being dispersed into the workroom air.	0.1	
Containment - no extraction	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. This class reflects “add on” enclosures and does not include inherently closed systems (like pipelines)		
- Low level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The process is contained with a loose lid or cover, which is not air tight. This includes tapping molten metal through covered launders and placing a loose lid on a ladle This class also includes bags or liners fitted around transfer points from source to receiving vessel. These include Muller seals, Stott head and single bag, and associated clamps and closures.	0.1	

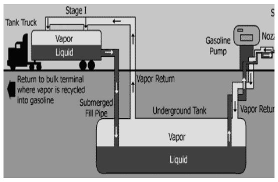
- Medium level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The material transfer is enclosed with the receiving vessel being docked or sealed to the source vessel. Examples include sealing heads, transfer containers and multiple o-rings. Inflatable packing head with continuous liner ensures a seal is maintained during the powder transfer and the continuous plastic liner prevents direct contact with the product. The correct type of tie off must be used.	0.01	
- High level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The substance is contained within a sealed and enclosed system. This class includes metal smelting furnaces or atomisation units. The material transfer is entirely enclosed with high containment valves (e.g. split butterfly valves and direct couplings, which consist of two sections which connect together to allow the opening of the valve). At the end of the material transfer the two halves are separated, forming a seal on both the process equipment and the material container. The system is designed to minimise the surface area which can contact the material or pairs of valves with wash space between them.	0.001	
Local exhaust ventilation (LEV) - Receiving hoods			
> Canopy hoods	A canopy hood placed over a hot process to receive the plume of contaminant-laden air given off. For cold processes with no thermal uplift, canopy hoods are ineffective (HSE, 2008).	0.5	

> Other receiving hoods	A receiving hood can be applied wherever a process produces a contaminant cloud with a strong and predictable direction (e.g. a grinding wheel). The contaminant cloud is propelled into the hood by process-induced air movement. The face of the hood must be big enough to receive the contaminant cloud and the extraction empties the hood of contaminated air at least as fast as it is filled.	0.2	
- Capturing hoods			
> Movable capturing hoods	Movable LEV systems such as hoods with extendable arms. The design of the system does not prevent work being performed outside the capture zone of the system and worker behaviour can influence the effectiveness of the system.	0.5	
> Fixed capturing hoods	Fixed capturing hoods located in close proximity of and directed at the source of emission. The design is such that the work is performed in the capture zone of the system and the capture is indicated at the workplace.	0.1	
> On-tool extraction	LEV systems integrated in a process or equipment that cannot be separated from the primary emission source.	0.1	
Enclosing hoods			
- Fume cupboard	Any form of permanent encapsulation or encasing of the source of which maximally one side is open with a well designed local exhaust ventilation system (e.g. laminar air flow). The design of both the enclosure and the ventilation system is such that the influence of worker behaviour is minimal (e.g. an alarm system prevents the worker from using the fume cupboard in case the system is not working properly).	0.01	

> Horizontal/downward laminar flow booth	In a horizontal laminar flow booth, contaminated air is extracted through holes situated at the rear of the booth which creates a horizontal laminar air flow. The air is filtered prior to being discharged to the atmosphere. The booth contains the source and has maximally one side open. In a downward laminar flow booth, a curtain of descending laminar air flow is created between the ceiling and the rear of the booth where exhaust grills are located in the lower section. The booth contains the source and has maximally one side open.. Spray rooms and laminar down-flow booths (with the size of a room which contains both the source and the worker) are not considered to be a localised control and will be treated together with the dispersion questions at a later stage.	0.1	
- Other enclosing hoods	Any form of permanent encapsulation or encasing of the source of which maximally the front side is open with a proper local exhaust ventilation system.	0.1	
- Other LEV systems	In case the type of local exhaust ventilation system is unknown or not specified, this default LEV category can be selected. Note that this default category results in a low reduction of the estimated personal exposure level. An attempt should be made to more specifically define the type of local exhaust ventilation.	0.5	
Glove bags and glove boxes			
- Glove bags	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way. An adaption piece is necessary between the glove bag and the process equipment. The glove bag must be designed specifically for the task and the quantity of material to be handled. Various other items such as pass-out boxes, inlet filters, and drains are added to meet specific needs. Note: use of glove bags does not negate the need to implement a long term permanent technological solution.		
> Glove bags (non-ventilated)	Large plastic bags, available in different design and sizes are fitted with gloves	0.01	

	which allow products to be handled in a contained way without exhaust ventilation.		
> Glove bags (ventilated or kept under negative pressure)	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way. The glove bag is maintained with filtration and ventilation at specific flow rates	0.001	
- Glove boxes	Any form of permanent encapsulation or encasing of the source (which are not opened during the given activity) with a well designed local exhaust ventilation system. The design of both the enclosure and the ventilation system is such that the influence of worker behaviour is minimal (e.g. the enclosure cannot be opened before the substance is properly vented).		
> Low specification glove box	A low specification glove box is specified as: • Single chamber, simple access doors or pass box • Not safe change glove • Single HEPA filtered extract air • Not safe change filters • Manual cleaning	0.001	
> Medium specification glove box	A medium specification glove box is specified as: • Two or more chambers if large area bin docking or high dust levels expected • Safe change or push through filters are required • Solid (stainless steel) construction for durability. • Size is dependent on the task to be carried out • Safe change filters are required • Air should be single or double HEPA filtered and or exhausted directly to the atmosphere after single HEPA filtration. • The equipment should be maintained under negative pressure and the air flow and filter condition continuously monitored. • Emergency air extraction should start up automatically in the event of a leak or a damaged glove. • Interlocked air locks should be used to prevent high dust concentrations	0.0003	

	in the area of the transfer ports and reduce risk. (escape of the contaminant during transfer of materials into and out of the glove box). • Glove changes should be able to be carried out without breaking containment • Waste disposal ports are required. Correct sealing of continuous liners. • Manual cleaning	
> High specification glove box	A high specification glove box is specified as: • Two or more chambers • Safe change filters are required • Stainless steel construction • Size is dependent on the task to be carried out • Safe change filters are required • Air should be single or double HEPA filtered and or exhausted directly to the atmosphere after single HEPA filtration. • The equipment should be maintained under negative pressure and the air flow and filter condition continuously monitored. • Emergency air extraction should start up automatically in the event of a leak or a damaged glove. • Interlocked air locks should be used to prevent the escape of the contaminant during transfer of materials into and out of the glove box. • Glove changes should be able to be carried out without breaking containment • Waste disposal ports are required. • Integrated sampling and contained drum charging • Sealed and high containment transfer ports (contained transfer couplings, rapid transfer ports (RTPs), alpha/beta valves etc.) • Including waste removal and change parts • Wash in place • Alarmed	0.0001

Vapour recovery systems	Reduction of vapour emission during storage, loading and off-loading of gasoline or other liquids, and during re-fuelling of a vehicle, by the combination of a vapour collection system and a vapour control unit. Vapour collection is a passive process where the volume of liquid transferred is equal to the volume of vapour transported back to the tank. The system only works properly when no other escape openings are present.	0.2	

Guidance text:

Select the general type of localized controls present for this emission source.
Depending on your selection you may be required to further define the localized controls.
Spray rooms are not considered to be a localized control and will be treated together with the dispersion questions at a later stage.

Question 80.5:

Are there any secondary control measures in close proximity of the far field emission source intended to minimize emissions from the source in addition to the primary control measure indicated in the previous question? *[Warning text: "the control measure should cover the whole activity"]*.

Answer:

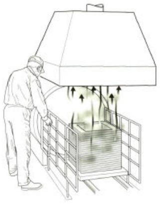
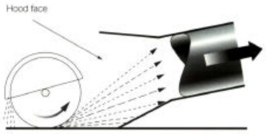
Dropdown list with following possibilities:

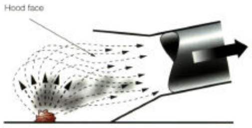
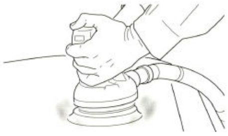
- No secondary localized controls
- Suppression techniques *[This class should only be visible if the answer to question 3 = "*Powdered, granular or pelletized material" or "Solid objects"] -> *go to separate dropdown list for suppression techniques below*
    - Knockdown suppression
    - Wetting at the point of release
- Containment – no extraction *[If this class is selected the answer to the containment question in the activity emission potential should be overruled and set to 'open process']*
    - Low level containment
    - Medium level containment
    - High level containment
- Local exhaust ventilation (LEV) -> *go to separate dropdown list for LEV below*
    - Receiving hoods -> *go to separate dropdown list for receiving hoods below*
        - Canopy hood
        - Other receiving hoods
    - Capturing hoods -> *go to separate dropdown list for capturing hoods below*
        - Movable capturing hood
        - Fixed capturing hood
        - On-tool extraction
    - Enclosing hoods -> *go to separate dropdown list for enclosing hoods below.*
        - Fume cupboard
        - Horizontal/downward laminar flow booth
        - Other enclosing hoods
    - Other LEV systems
- Glove boxes and glove bags *[If this class is selected the answer to the containment question in the activity emission potential should be overruled and set to 'open process']*
        - Glove bags
            - Glove bags (non-ventilated)
            - Glove bags (ventilated or kept under negative pressure)

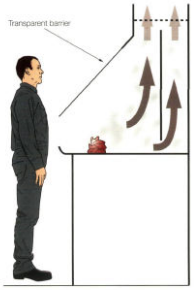
  - ▪ Glove boxes
    - Low specification glove box
    - Medium specification glove box
    - High specification glove box / isolator
- Vapour recovery systems

Descriptions and assigned values of each category are given in the table below.

Classification	**Description**	**Assigned typical value**	**Guidance images**
No secondary localized controls	No secondary control measures in close proximity of the source.	1	
Suppression techniques			
Knockdown suppression *[This class should only be visible if the answer to question 3 = “*Powdered, granular or pelletized material” or “Solid objects”]	Post generation suppression of airborne contaminants to reduce dust levels. Knockdown of a contaminant after it has been emitted.	0.7	
Wetting at the point of release *[This class should only be visible if the answer to question 3 = “*Powdered, granular or pelletized material” or “Solid objects”]	Wetting systems that wet the process at the point of release (focusing on the emission source) to agglomerate and bind the fine particles to prevent dust from being dispersed into the workroom air.	0.1	 
Containment - no extraction	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. This class reflects “add on” enclosures and does not include inherently closed systems (like pipelines)		
- Low level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The process is contained with a loose lid or cover, which is not air tight. This includes tapping molten metal through covered launders and placing a loose lid on a ladle This class also includes bags or liners fitted around transfer points from source to receiving vessel. These include Muller seals, Stott head and single bag, and associated clamps and closures.	0.1	

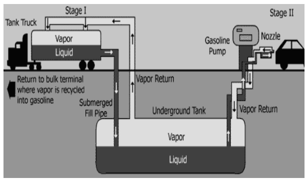
- Medium level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The material transfer is enclosed with the receiving vessel being docked or sealed to the source vessel. Examples include sealing heads, transfer containers and multiple o-rings. Inflatable packing head with continuous liner ensures a seal is maintained during the powder transfer and the continuous plastic liner prevents direct contact with the product. The correct type of tie off must be used.	0.01	
- High level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The substance is contained within a sealed and enclosed system. This class includes metal smelting furnaces or atomisation units. The material transfer is entirely enclosed with high containment valves (e.g. split butterfly valves and direct couplings, which consist of two sections which connect together to allow the opening of the valve). At the end of the material transfer the two halves are separated, forming a seal on both the process equipment and the material container. The system is designed to minimise the surface area which can contact the material or pairs of valves with wash space between them.	0.001	
Local exhaust ventilation (LEV) - Receiving hoods			
> Canopy hoods	A canopy hood placed over a hot process to receive the plume of contaminant-laden air given off. For cold processes with no thermal uplift, canopy hoods are ineffective.	0.5	
> Other receiving hoods	A receiving hood can be applied wherever a process produces a contaminant cloud with a strong and predictable direction (e.g. a grinding wheel). The contaminant cloud is propelled into the hood by process-	0.2	

	induced air movement. The face of the hood must be big enough to receive the contaminant cloud and the extraction empties the hood of contaminated air at least as fast as it is filled.		
- Capturing hoods			
> Movable capturing hoods	Movable LEV systems such as hoods with extendable arms. The design of the system does not prevent work being performed outside the capture zone of the system and worker behaviour can influence the effectiveness of the system.	0.5	
> Fixed capturing hoods	Fixed capturing hoods located in close proximity of and directed at the source of emission. The design is such that the work is performed in the capture zone of the ventilation system and the capture is indicated at the workplace.	0.1	
> On-tool extraction	LEV systems integrated in a process or equipment that cannot be separated from the primary emission source.	0.1	
- Enclosing hoods			
> Fume cupboard	Any form of permanent encapsulation or encasing of the source of which maximally one side is open with a well designed local exhaust ventilation system (e.g. laminar air flow). The design of both the enclosure and the ventilation system is such that the influence of worker behaviour is minimal (e.g. an alarm system prevents the worker from using the fume cupboard in case the system is not working properly).	0.01	
> Horizontal/downward laminar flow booth	In a horizontal laminar flow booth, contaminated air is extracted through holes situated at the rear of the booth which creates a horizontal laminar air flow. The air is filtered prior to being discharged to the atmosphere. The booth contains the source and has maximally one side open. In a downward laminar flow booth, a curtain of descending laminar air flow is created between the ceiling and the rear of the booth where exhaust grills are located in the lower section. The booth	0.1	

	contains the source and has maximally one side open.. Spray rooms and laminar down-flow booths (with the size of a room which contains both the source and the worker) are not considered to be a localised control and will be treated together with the dispersion questions at a later stage.		
> Other enclosing hoods	Any form of permanent encapsulation or encasing of the source of which maximally the front side is open with a proper local exhaust ventilation system.	0.1	
- Other LEV systems	In case the type of local exhaust ventilation system is unknown or not specified, this default LEV category can be selected. Note that this default category results in a low reduction of the estimated personal exposure level. An attempt should be made to more specifically define the type of local exhaust ventilation.	0.5	
Glove bags and glove boxes			
- Glove bags	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way. An adaption piece is necessary between the glove bag and the process equipment. The glove bag must be designed specifically for the task and the quantity of material to be handled. Various other items such as pass-out boxes, inlet filters, and drains are added to meet specific needs. Note: use of glove bags does not negate the need to implement a long term permanent technological solution.		

> Glove bags (non-ventilated)	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way without exhaust ventilation.	0.01	
> Glove bags (ventilated or kept under negative pressure)	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way. The glove bag is maintained with filtration and ventilation at specific flow rates	0.001	
- Glove boxes	Any form of permanent encapsulation or encasing of the source (which are not opened during the given activity) with a well designed local exhaust ventilation system. The design of both the enclosure and the ventilation system is such that the influence of worker behaviour is minimal (e.g. the enclosure cannot be opened before the substance is properly vented).		
> Low specification glove box	A low specification glove box is specified as: • Single chamber, simple access doors or pass box • Not safe change glove • Single HEPA filtered extract air • Not safe change filters • Manual cleaning	0.001	
> Medium specification glove box	A medium specification glove box is specified as: • Two or more chambers if large area bin docking or high dust levels expected • Safe change or push through filters are required • Solid (stainless steel) construction for durability. • Size is dependent on the task to be carried out • Safe change filters are required • Air should be single or double HEPA filtered and or exhausted directly to the atmosphere after single HEPA filtration. • The equipment should be maintained under negative pressure and the air flow and filter condition continuously monitored.	0.0003	

	• Emergency air extraction should start up automatically in the event of a leak or a damaged glove. • Interlocked air locks should be used to prevent high dust concentrations in the area of the transfer ports and reduce risk. (escape of the contaminant during transfer of materials into and out of the glove box). • Glove changes should be able to be carried out without breaking containment • Waste disposal ports are required. Correct sealing of continuous liners. • Manual cleaning	
> High specification glove box	A high specification glove box is specified as: • Two or more chambers • Safe change filters are required • Stainless steel construction • Size is dependent on the task to be carried out • Safe change filters are required • Air should be single or double HEPA filtered and or exhausted directly to the atmosphere after single HEPA filtration. • The equipment should be maintained under negative pressure and the air flow and filter condition continuously monitored. • Emergency air extraction should start up automatically in the event of a leak or a damaged glove. • Interlocked air locks should be used to prevent the escape of the contaminant during transfer of materials into and out of the glove box. • Glove changes should be able to be carried out without breaking containment • Waste disposal ports are required. • Integrated sampling and contained drum charging • Sealed and high containment transfer ports (contained transfer couplings, rapid transfer ports (RTPs), alpha/beta valves etc.) • Including waste removal and change parts • Wash in place	0.0001

	• Alarmed		
Vapour recovery systems	Reduction of vapour emission during storage, loading and off-loading of gasoline or other liquids, and during re-fuelling of a vehicle, by the combination of a vapour collection system and a vapour control unit. Vapour collection is a passive process where the volume of liquid transferred is equal to the volume of vapour transported back to the tank. The system only works properly when no other escape openings are present.	0.2	

Guidance text:

Select the secondary type of localized controls present for this emission source.
Depending on your selection you may be required to further define the localized controls.
The system is not protected against any non-existing combinations of localized controls, so be aware to only select a secondary localized control that can be used in combination with the primary localized control indicated in the previous questions.

4.12 Surface contamination / fugitive emission sources

Question 81:
Is the process fully enclosed and is the integrity of that enclosure regularly monitored?
Answer:
Dropdown list with following possibilities:

- Yes -> *assign value from table below and go to question 84*
- No

Question 82:
Are demonstrable and effective housekeeping practices in place (e.g. daily cleaning using appropriate methods (e.g. vacuum), preventive maintenance of machinery and control measures, and use of protective clothing that will repel spills and reduce personal cloud)?
Answer:
Dropdown list with following possibilities:

- Yes -> *assign value from table below and go to question 84*
- No

Question 83:
Are general housekeeping practices in place?
Answer:
Dropdown list with following possibilities:

- Yes
- No

Descriptions and assigned values of each category are given in the table below:

Scenario descriptor	Modifying factor Low-volatile liquid aerosols (incl. powders dissolved in a liquid)	Modifying factor Solid aerosols and volatile liquids (vapours)
Default level (no specific cleaning practices, no protective clothing that repel spills, process not fully enclosed)	0.01	0.01
General good housekeeping practices	0.003	0.003
Demonstrable and effective housekeeping practices (examples include daily cleaning using appropriate methods (e.g. vacuum), preventive maintenance of machinery and control measures, and use of protective clothing that will repel spills and reduce personal cloud)	0.001	0.001
Process fully enclosed (air tight) and the integrity of the enclosure is monitored at least once a month. The containment is not breached for example for sampling or routine cleaning.	0	0

Guidance text:

Emissions from contaminated surfaces arise from the evaporation of liquids or the re-suspension of dusts from leaks, spills or other sources that have produced surface contamination. Surfaces that may be contaminated include work surfaces, floors, walls, clothing, tools, process equipment, and used rags. Contamination may arise due to leaks or spills, or in the case of particles, deposition from the airborne state. Exposure from these sources will occur through re-suspension of settled dust or evaporation of spilled liquids.

Fugitive emissions are unintended and unpredictable leaks from process equipment that are not yet classified as a near-field or far-field source.

4.13 Dispersion

Question 84:

Is the work performed indoors, outdoors or in a spray booth or downward laminar flow booth?

Answer:

Dropdown list with following possibilities:

- Indoors -> *go to question on room size*
    - ***Question 85:*** What is the room size of the work area?
        - Any size workroom
        - Large workrooms only
        - Small workrooms only
        - 30 m^3
        - 100 m^3
        - 300 m^3
        - 1000 m^3
        - 3000 m^3
    - ***Question 86:*** What is the ventilation rate of the general ventilation system in the work area?
        - No restriction on general ventilation characteristics

        - Only good natural ventilation
        - Mechanical ventilation giving at least 1 ACH
        - Specialised room ventilation with more than 10 ACH
        - 0.3 air changes per hour (ACH)
        - 1 air changes per hour (ACH)
        - 3 air changes per hour (ACH)
        - 10 air changes per hour (ACH)
        - 30 air changes per hour (ACH)
- Outdoors (*clarifying text: "Only for situations where there are no or few boundaries nearby, i.e. the source is not located close to walls or in an enclosed courtyard. If this is not the case, the assessor should assume the work is essentially carried out indoors in an appropriately sized room.") -> go to separate dropdown list for outdoors*
    - ***Question 86.1***: Is the source located close to buildings?
        - Yes
        - No
- Spray room.
    - Cross-flow spray room. The spray room must meet the following conditions:
        - The spray room is a fully enclosed, unidirectional spray room of volume between 30 and 1000 m^3 with at least 10 air changes per hour;
        - the spray room has been designed by a competent ventilation engineer, the airflow performance is regularly checked and the ventilation system is maintained;
        - the spray room needs to run under negative pressure (i.e. so any air leakage is inward);
        - the workers in the spray room must be properly trained in correctly using the room (e.g. operation of the ventilation system, good positioning of the worker relative to the source and the ventilation, knowing the ventilation clearance time of the room).
    - Down-flow spray room. The spray room must meet the following conditions:
        - The spray room is a fully enclosed, unidirectional downflow spray room of volume between 30 and 1000 m^3 with at least 10 air changes per hour;
        - the spray room has been designed by a competent ventilation engineer, the airflow performance is regularly checked and the ventilation system is maintained;
        - the spray room needs to run under negative pressure (i.e. so any air leakage is inward);
        - the workers in the spray room must be properly trained in correctly using the room (e.g. operation of the ventilation system, good positioning of the worker relative to the source and the ventilation, knowing the ventilation clearance time of the room).
- Downward laminar flow booth
    - No barriers or screens
    - Partial screen
    - Partial screen fitted with glove ports
    - Full screen fitted with glove ports

Dispersion category	**Description**
Indoors	Both the source and the worker are located indoors. The indoor environment should be enclosed by walls on each side and a

	roof on top. A garage with the garage door open should be treated as an indoor environment.
Outdoors	Both the source and the worker are located outdoors. It is assumed there are two situations outdoors where the scenario may be located: close to buildings or away from buildings or other obstructions.
Spray room	The spray room is defined as: a fully enclosed room between 30 and 1000 m3 with at least 10 air changes per hour. The spray room needs to be regularly checked and maintained. The workers in the spray room need to be properly trained in correctly using the room (e.g. wearing air-fed breathing equipment, knowing the clearance time of the room, good positioning of the worker relative to the source and the ventilation). The spray room needs to run under negative pressure (so any air leakage is inward).
Downward laminar flow booth	A curtain of descending laminar air is created between the ceiling and the rear of the booth where exhaust grilles are located at the lower section. The worker must not stand at the exhaust grilles and standing in-between the source and the grilles will reduce the effectiveness of the booth. The exhaust volume is typically between 3500-4000 m3/h (per 1m width). • The booths **must** completely enclose the work task and the worker. • Booth sizes are adaptable to the work task and process equipment and can have varying levels of filtration. • The filter should have high dust holding capacity, and performance and volume air flow need to be checked regularly. • For booth down flow and laminar flow booths capture velocity approx 0.5 m/second. • A safe work line (SWL) marks the limit of effective containment and dust capture. • Flow booths can be equipped with partial or full screens with glove ports, potentially offering a further level of containment. 
> Partial screen	Partial screens covering the majority of the front of the process/booth; however there may be relatively small openings for operator hands and/or gaps at the top and bottom of the booth.
> Partial screen fitted with glove ports	Partial screen covering the majority of front of process/booth and is fitted with glove ports to allow the operator handle the product;

	however there may be relatively small gaps at the top and/or bottom of the booth. 
> Full screen fitted with glove ports	Full screen covering the entire front of the process/booth and is fitted with glove ports

Descriptions and assigned values of each category are given in the table below. Based on the answer to question 16 and the exposure form (dust, mist, vapour or fume), the correct multiplier should be selected from the tables below.

Indoor Near-Field Multipliers for broader room size categories (long-term; 8-hour tasks)

Room volume descriptor	Modifiers for use in the ART model
Any size workroom	Choose from all relevant cells between 30 and 3000 m^3, with equal probability
Large workrooms only	Choice from relevant cells 300 to 3000 m^3, with equal probability
Small workrooms only	Choice from relevant cells 30 to 100 m^3, with equal probability

Indoor Near-Field Multipliers for broader ventilation rate categories (long-term; 8-hour tasks)

Ventilation rate descriptor	Modifiers for use in the ART model
No restriction on general ventilation characteristics	Choose from all relevant cells 0.3 to 3 ACH with equal probability
Only good natural ventilation	Choice from all relevant cells 0.3, 1 and 3 ACH with weighting 20%, 40%, 40%
Mechanical ventilation giving at least 1 ACH	Choice from all relevant cells 1, 3, 10 and 30 ACH with weighting 55%, 25%, 15%, 5%.
Specialised room ventilation with more than 10 ACH	Choice from all cells 10 to 30 ACH with equal probability

Indoor Near-Field Multipliers for vapours (volatile liquids) and gases (long-term; 8-hour tasks)

Room volume (m^3)	**0.3 ACH**	**1 ACH**	**3 ACH**	**10 ACH**	**30 ACH**
30	36	17	7	3	1.6
100	12	6	2.7	1.5	1.1
300	4.8	2.6	1.6	1.1	1.0
1000	2.1	1.5	1.1	1.0	1.0
3000	1.3	1.1	1.0	1.0	1.0

Indoor Far-Field Multipliers for vapours (volatile liquids) and gases (long-term; 8-hour tasks)

Room volume (m^3)	**0.3 ACH**	**1 ACH**	**3 ACH**	**10 ACH**	**30 ACH**
30	35	16	6.1	1.9	0.6
100	12	5	1.8	0.6	0.2
300	3.9	1.6	0.6	0.2	0.1
1000	1.2	0.5	0.2	0.06	0.02
3000	0.4	0.2	0.1	0.02	0.01

Indoor Near-Field Multipliers for dusts, mists (low-volatile liquids), powders in liquids, paste/slurry, solid objects and fibres (long-term; 8-hour tasks)

Room volume (m^3)	0.3 ACH	1 ACH	3 ACH	10 ACH	30 ACH
30	6.3	4.0	2.4	1.4	1.0
100	2.7	1.8	1.3	1.0	0.8
300	1.5	1.1	0.9	0.8	0.8
1000	1.0	0.8	0.8	0.7	0.7
3000	0.8	0.8	0.7	0.7	0.7

Indoor Far-Field Multipliers for dusts, mists (low-volatile liquids), powders in liquids, paste/slurry, solid objects and fibres (long-term; 8-hour tasks)

Room volume (m^3)	0.3 ACH	1 ACH	3 ACH	10 ACH	30 ACH
30	5.7	3.4	1.7	0.8	0.3
100	2.1	1.2	0.6	0.3	0.1
300	0.8	0.4	0.2	0.1	0.04
1000	0.2	0.1	0.1	0.03	0.01
3000	0.1	0.05	0.02	0.01	0.004

Indoor Near-Field Multipliers for fumes (long-term; 8-hour tasks)

Room volume (m^3)	0.3 ACH	1 ACH	3 ACH	10 ACH	30 ACH
30	29.3	14.9	6.5	2.7	1.6
100	10.5	5.3	2.6	1.5	1.1
300	4.3	2.4	1.5	1.1	1.0

1000	2.0	1.4	1.1	1.0	1.0
3000	1.3	1.1	1.0	1.0	0.9

Indoor Far-Field Multipliers for fumes (long-term; 8-hour tasks)

Room volume (m^3)	0.3 ACH	1 ACH	3 ACH	10 ACH	30 ACH
30	28.5	14.0	5.6	1.8	0.6
100	9.6	4.4	1.7	0.5	0.2
300	3.4	1.5	0.6	0.2	0.1
1000	1.0	0.5	0.2	0.1	0.02
3000	0.3	0.2	0.1	0.02	0.01

Outdoor Multipliers for vapours (volatile liquids), gases and fumes

	Close to buildings	**Far from buildings**
NF	1	0.3
FF (1 – 4 m)	0.03	0.01
FF (> 4 m)	0.01	0.003

Outdoor Multipliers for dusts, mists (low-volatile liquids), powders in liquids, paste/slurry, solid objects and fibres

	Close to buildings	**Far from buildings**
NF	0.75	0.2
FF (1 – 4 m)	0.015	0.005
FF (> 4 m)	0.005	0.00167

Spray room multiplier for vapours (volatile liquids), gases and fumes (long-term; 8-hour tasks)

Description	**Assigned value**
Cross-flow spray room	1.0
Down-flow spray room	0.3
Downward laminar flow booth	0.3
- Downward laminar flow booth using partial screen	0.2
- Downward laminar flow booth using partial screen fitted with glove ports	0.15
- Downward laminar flow booth using full screen fitted with glove ports	0.015

Spray room multiplier for dusts, mists (low-volatile liquids), powders in liquids, paste/slurry, solid objects and fibres (long-term; 8-hour tasks)

Description	**Assigned value**

Cross-flow spray room	0.7
Down-flow spray room	0.2
Downward laminar flow booth	0.2
- Downward laminar flow booth using partial screen	0.15
- Downward laminar flow booth using partial screen fitted with glove ports	0.1
- Downward laminar flow booth using full screen fitted with glove ports	0.01

Guidance text:

Dispersion is the movement of a contaminant from a source throughout the work area, giving rise to varying spatial concentrations. The dispersion is dependent on the size of the workroom and the air changes in this room (with personal exposure levels being higher in a small poorly ventilated room).

Broad categories of room sizes and ventilation rates can be selected. Alternatively, the room size and ventilation rate can be selected from the list of specific room sizes and ventilation rates. Note, if the room size or air change rate is between two categories, then the next lower category should be selected for a specific situation, e.g. a 200 m^3 room with 0.7 ACH should have the multiplier for 100 m^3 and 0.3 ACH selected.

4.14 Secondary FF sources

Question 89:

Are secondary sources present in the workroom in addition to the source in the breathing zone of the worker?

Answer:

Dropdown list with following possibilities:

- Yes -> *go to question 89.5 or to question 90 if answer to Q 84 not equals 'outdoors'. [If a FF source is present in addition to the NF source, the FF dispersion multipliers from the above tables apply.]*
- No -> *no further questions*

Guidance text:

Secondary far field sources can be co-workers, machines or evaporating baths, objects or surfaces.

[*Question 89.5 should only be asked if the answer to Q84 = 'outdoors'*]

- ***Question 89.5:*** Is the worker located further than 4 meters from this far field source?
    - Yes
    - No

4.15 Substance emission potential (FF source)

Question 90:

What is the product type of the substance/preparation?

Answer:

Dropdown list with following possibilities:

- Powdered, granular or pelletized material

This category also includes liquids incorporated in granular or pelletized material (e.g. preservative in wood chips) -> *go to question 91*
- Solid objects
  This category also includes liquids incorporated or on the surface of this material (e.g. preservative in timber)
- Liquids
  This category also includes solids incorporated in a liquid matrix (e.g. copper in anti-fouling paint)-> *go to question 96*
- *Powders dissolved in a liquid or incorporated in a liquid matrix (e.g. copper in anti-fouling paint) -> go to question 102.5.1*
- Paste, slurry or clearly (soaked) wet powder (not containing volatile liquid components) -> go to question 102.1
- Hot or molten metal -> go to question 102.6
- Fibrous material. *[This is outside the applicability domain of the beta version. Should be visible but not selectable.]*
- Gas *[This is outside the applicability domain of the beta version. Should be visible but not selectable.]*

Guidance text:

Select the type of the product at the beginning of the activity.

4.15.1 Powders, granules or pelletized material

Question 91:

What is the measured dustiness of the material (mg/kg for inhalable fraction)?

Answer:

[Numerical value ($0<\text{dustiness}\leq100000$)]. *[Based on the answer, one of the dustiness classes in question 5 is selected.]*

Guidance text:

Dustiness may be measured by two methods, the rotating drum test and the continuous single drop test, which is described in detail in CEN EN 15051 (2006). The two test methods do not always rank materials in the same order and users should therefore choose the method that is most appropriate for the material and handling process they wish to simulate.

Question 92:

If the dustiness of the material was not measured: To which dustiness class does the substance belong?

Answer:

Dropdown list with following possibilities:
- Extremely fine and light powder.
- Fine dust.
- Coarse dust.
- Granules, flakes or pellets.
- Firm granules, flakes or pellets.

Descriptions and assigned values of each category are given in the table below:

Classification	Description	Assigned value	Indicative dustiness test result (inhalable fraction)*	Guidance images
Extremely fine and light powder	A powdered product containing very fine, free flowing, light particles. This category may also contain products with a mixture of very fine particles and large particles or granules. Handling the product in its dry form results in a dust cloud that remains airborne for a long time. The product may be wind swept: e.g., magnesium stearate.	1.0	> 5,000 mg/kg	
Fine dust	A powdered product containing fine particles. This category may also contain products with a mixture of fine particles and large particles or granules. Handling the product in its dry form results in a dust cloud that is clearly visible for some time: e.g., talcum powder, carbon black.	0.3	2,000 – 5,000 mg/kg	
Coarse dust	A powdered product containing coarse particles. Handling the product in its dry form results in a dust cloud that settles quickly due to gravity: e.g. sand.	0.1	501 - 2,000 mg/kg	
Granules, flakes or pellets	Granules or flakes may fall apart and crumble, resulting in only a very limited amount of fine particles. Handling the product does not result in a visible dust cloud; e.g., fertilizer, garden peat, animal pellets.	0.03	101 – 500 mg/kg	
Firm granules, flakes or pellets	Product does not result in dust emission without intentional breakage of products: e.g., firm polymer granules, granules covered with a layer of wax, a woodblock, a brick)	0.01	≤ 100 mg/kg	

Question 93:

What is the moisture content of the product?

Answer:

Dropdown list with following possibilities:

- Dry product (< 5 % moisture content)
- 5 - 10 % moisture content
- > 10% moisture content

Descriptions and assigned values of each category are given in the table below:

Classification	**Assigned value**
Dry product (< 5 % moisture content)	1.0
5 – 10 % moisture content	0.1
> 10 % moisture content	0.01

Guidance text:

Increasing the moisture content or adding other additives can reduce exposure potential. Water may have been added before handling the product or during handling. The latter is taken into account in the principal MF "localized control', whereas the former is considered an intrinsic property of the material.

Clearly (soaked) wet powdered material (like paste or slurry) should not be treated as a powder and the product type 'paste or slurry or clearly (soaked) wet powder' should be selected.

Question 93.5:

What is the weight fraction of the substance in the powder, granular or pelletized material? If the weight fraction of the substance in the material is not precisely known, pick one of the categories below.

Answer:

<Numeric field (0.0≤weight fraction≤1.0)> or alternatively dropdown list with following possibilities:

- Pure material (100%)
- Main component (50 – 90 %)
- Substantial (10 – 50 %)
- Minor (5 – 10 %)
- Small (1 – 5 %)
- Very small (0.5 – 1 %)
- Extremely small (0.1 – 0.5 %)
- Minute (0.01 – 0.1 %)
- Extremely minute (< 0.01 %)

If one of the above categories is selected, use the median from the table below in calculating the substance emission potential (E).

		Weight fractions	
Weight fraction categories	**Minimum**	**Median**	**Maximum**
Pure material	1	1	1
Main component	0.5	0.7	0.9
Substantial	0.1	0.3	0.5
Minor	0.05	0.075	0.1
Small	0.01	0.03	0.05
Very small	0.005	0.0075	0.01

Extremely small	0.001	0.003	0.005
Minute	0.0001	0.00055	0.001
Extremely minute	0	0.00005	0.0001

E_{solid} = Dustiness * moisture score * (median) weight fraction

[Go to question 16]

4.15.2 Solid objects

Question 94:
What is the weight fraction of the substance in the solid object? If the weight fraction is not precisely known, pick one of the categories below.
Answer:
<Numeric field (0.0≤weight fraction≤1.0)> or alternatively dropdown list with following possibilities:

- Pure material (100%)
- Main component (50 – 90 %)
- Substantial (10 – 50 %)
- Minor (5 – 10 %)
- Small (1 – 5 %)
- Very small (0.5 – 1 %)
- Extremely small (0.1 – 0.5 %)
- Minute (0.01 – 0.1 %)

If one of the above categories is selected, use the median from the table below in calculating the substance emission potential (E).

	Mole or weight fractions		
Mole/weight fraction categories	**Minimum**	**Median**	**Maximum**
Pure liquid	1	1	1
Main component	0.5	0.7	0.9
Substantial	0.1	0.3	0.5
Minor	0.05	0.075	0.1
Small	0.01	0.03	0.05
Very small	0.005	0.0075	0.01
Extremely small	0.001	0.003	0.005
Minute	0.0001	0.0006	0.001

Guidance text:

The fraction of the substance in the solid object should be estimated by expert judgement. For instance, if the quartz content in solid stone is 5%, then 0.05 should be entered here. For impregnated wood logs it will be more difficult to estimate the right proportion of substance in the log.

Question 95:
What is the material of the solid object?
Answer:

- Wood
- Stone
- Metal

- Plastic *[This is outside the applicability domain of the beta version. Should be visible but not selectable]*
- Leather *[This is outside the applicability domain of the beta version. Should be visible but not selectable]*
- Glass *[This is outside the applicability domain of the beta version. Should be visible but not selectable]*
- Textile fabrics *[This is outside the applicability domain of the beta version. Should be visible but not selectable]*
- Other *[This is outside the applicability domain of the beta version. Should be visible but not selectable]*

Question 95.5:
What is the moisture content of the solid object?
Answer:
Dropdown list with following possibilities:

- Dry solid object (< 5 % moisture content)
- 5 – 10 % moisture content
- > 10 % moisture content

Descriptions and assigned values of each category are given in the table below:

Classification	**Assigned value**
Dry solid object (< 5 % moisture content)	1.0
5 – 10 % moisture content	0.3
> 10 % moisture content	0.03

Guidance text:

Increasing the moisture content or adding other additives can reduce exposure potential. Water may have been added before handling the product or during handling. The latter is taken into account in the principal MF “localized control’, whereas the former is considered an intrinsic property of the material.

4.15.3 Liquids

Question 96:
What is the temperature of the liquid in the process (in Celsius)? If the process temperature of the liquid is not precisely known, pick one of the categories below.
Answer:
<Numeric field (0≤process temperature≤150)> [If temperature = 15-25 ºC then go to question 97. Else go to question 97.5]
Alternatively dropdown list with following possibilities:

- Hot processes (50 – 150 ºC) -> *go to question 97.5*
- Above room temperature (25 – 50 ºC) -> *go to question 97.5*
- Room temperature (15 – 25 ºC) -> *go to question 97*
- Below room temperature (< 15 ºC) -> *go to question 97.5*

If one of the above categories is selected, use the median process temperature (in Celsius) from the table below in calculating the vapour pressure.

Temperatures

	Minimum		Median		Maximum	
Temperature categories	°C	K	°C	K	°C	K
Hot processes	50	323	75	373	150	423
Above room temperature	25	298	37.5	310.5	50	323
Room temperature	15	288	20	293	25	298
Below room temperature	0	273	7.5	280.5	15	288

Guidance text:

Configure the process temperature then click Next to continue.

Question 97:

What is the vapour pressure (in Pascal) of the substance at room temperature?

Answer:

<Numeric field>

Guidance text:

Enter the vapour pressure (in Pascal) of the pure substance at room temperature (even if it is in a mixture).

Conversion table:

	Pa	**bar**	**atm**	**mmHg**	**Ib in^{-2} (psi)**
Pa	1	1.00x10^{-5}	1.01x10^{5}	7.50x10^{-3}	1.46 x 10^{-4}
bar	1.00x10^{5}	1	0.987	750	14.5
atm	1.01x10^{5}	1.013	1	760	14.7
mmHg	133	1.32x10^{-3}	1.31x10^{-3}	1	0.019
Ib in^{-2} (psi)	6870	0.068	0.068	51.7	1

[If vapour pressure ≤ 10 then go to question 99*]*
[If vapour pressure > 10 then go to question 101*]*
[If vapour pressure > 100,000 *then warning text: "Substance with a vapour pressure of > 100,000 Pa at room temperature are considered to be gases. The difference between a vapour and a gas is that, under ambient environmental conditions, a vapour is present in equilibrium with the volatile liquid. In contrast, for a gas under normal environmental conditions there will be no liquid present. The ART model is not yet suitable for assessing exposure to gases."]*

Question 97.5:

If known, what is the vapour pressure (in Pascal) of the substance at this process temperature?

Answer:

<Numeric field [>0]>

Guidance text:

Enter the vapour pressure (in Pascal) of the substance at process temperature (even if it is in a mixture).

Conversion table:

	Pa	**bar**	**atm**	**mmHg**	**Ib in^{-2} (psi)**
Pa	1	1.00x10^{-5}	1.01x10^{5}	7.50x10^{-3}	1.46 x 10^{-4}

bar	1.00×10^5	1	0.987	750	14.5
atm	1.01×10^5	1.013	1	760	14.7
mmHg	133	1.32×10^{-3}	1.31×10^{-3}	1	0.019
Ib in^{-2} (psi)	6870	0.068	0.068	51.7	1

[If vapour pressure ≤ 10 then go to question 99*]*
[If vapour pressure > 10 then go to question 101*]*
[If vapour pressure > 100,000 *then warning text: "Substance with a vapour pressure of > 100,000 Pa at room temperature are considered to be gases. The difference between a vapour and a gas is that, under ambient environmental conditions, a vapour is present in equilibrium with the volatile liquid. In contrast, for a gas under normal environmental conditions there will be no liquid present. The ART model is not yet suitable for assessing exposure to gases."]*

Question 98:
If the vapour pressure at process temperature is not known, what is the boiling point temperature of the substance in the liquid of interest (in Celsius)?
Answer:
<Numerical field [lower limit depending on the process temperature - 2727]>

Guidance text:

Enter the boiling temperature (in degrees Celsius) of the pure substance. In case of complex mixtures provide the lowest boiling point temperature of a single agent in the mixture.
Both the boiling temperature and the process temperature should be in degrees Celsius. The boiling temperature should be greater than the process temperature.

The vapour pressure at process temperature results from the following equation:

Vapour pressure = $101000 \times e^{(-10.6 \times (((\text{boiling temperature (in Celsius)} + 273.15)/(\text{process temperature (in Celsius)} + 273.15))-1))}$
Both the boiling temperature and the process temperature should be in degrees Celsius. The boiling temperature should be greater than the process temperature.

[If vapour pressure ≤ 10 then go to question 99*]*
[If vapour pressure > 10 then go to question 101*]*
[If vapour pressure > 100,000 then warning text: "Substance with a vapour pressure of > 100,000 Pa at room temperature are considered to be gases. The difference between a vapour and a gas is that, under ambient environmental conditions, a vapour is present in equilibrium with the volatile liquid. In contrast, for a gas under normal environmental conditions there will be no liquid present. The ART model is not yet suitable for assessing exposure to gases."]

4.15.3.1 Low-volatile liquids

Question 99:
[Warning text: The substance is considered low-volatile and exposure to mists is estimated.]
What is the weight fraction of the substance in the liquid mixture? If the weight fraction of the substance in the liquid mixture is not precisely known, pick one of the categories below.
Answer:
<Numeric field (0.0≤weight fraction≤1.0)> or alternatively dropdown list with following possibilities:

- Pure liquid (100%)
- Main component (50 – 90 %)

- Substantial (10 – 50 %)
- Minor (5 – 10 %)
- Small (1 – 5 %)
- Very small (0.5 – 1 %)
- Extremely small (0.1 – 0.5 %)
- Minute (0.01 – 0.1 %)

If one of the above categories is selected, use the median from the table below in calculating the substance emission potential (E).

	Mole or weight fractions		
Mole/weight fraction categories	**Minimum**	**Median**	**Maximum**
Pure liquid	1	1	1
Main component	0.5	0.7	0.9
Substantial	0.1	0.3	0.5
Minor	0.05	0.075	0.1
Small	0.01	0.03	0.05
Very small	0.005	0.0075	0.01
Extremely small	0.001	0.003	0.005
Minute	0.0001	0.0006	0.001

Question 100:
What is the viscosity of the substance/preparation?
Answer:
Dropdown list with following possibilities:
- Liquids with low viscosity (like water)
- Liquids with medium viscosity (like oil)

Descriptions and assigned values of each category are given in the table below:

Classification	**Assigned value**
Liquids with low viscosity (like water)	1.0
Liquids with medium viscosity (like oil)	0.3

The substance emission potential of low-volatile substance i (E_i) is calculated by using:
E_i *= (10/30000) * (median) mol fraction * viscosity.*

Go to question 103

4.15.3.2 Volatile liquids

Question 101:

[Warning text: The substance is considered volatile and exposure to vapours is estimated.]
What is the mole fraction of the substance in the liquid mixture? If the mole fraction is unknown, assume that this is the same as the weight fraction. If the weight fraction of the substance in the liquid mixture is not precisely known, pick one of the categories below.
Answer:

<Numeric field (0.0≤mole fraction≤1.0> or alternatively dropdown list with following possibilities:

- Pure liquid (100%)
- Main component (50 – 90 %)
- Substantial (10 – 50 %)
- Minor (5 – 10 %)
- Small (1 – 5 %)
- Very small (0.5 – 1 %)
- Extremely small (0.1 – 0.5 %)
- Minute (0.01 – 0.1 %)

If one of the above categories is selected, use the median from the table below in calculating the substance emission potential (E).

	Mole or weight fractions		
Mole/weight fraction categories	**Minimum**	**Median**	**Maximum**
Pure liquid	1	1	1
Main component	0.5	0.7	0.9
Substantial	0.1	0.3	0.5
Minor	0.05	0.075	0.1
Small	0.01	0.03	0.05
Very small	0.005	0.0075	0.01
Extremely small	0.001	0.003	0.005
Minute	0.0001	0.0006	0.001

Question 102:
If known, please provide the activity coefficient for the substance in this mixture?
(One method for estimating activity coefficient for liquid mixtures is using the UNIFAC method, which can be found at http://www.pvv.org/~randhol/xlunifac/). The default value is set at 1.

Answer:
<Numerical field [0.001-1000]>
[Default value = 1]

The table below provide some guidance for choosing the activity coefficient.

Product	**Activity coefficient**
Pure liquid	1
Liquid solutions	XLUNIFAC (or similar)
Similar organic solvents	1-4
Insoluble solids	1 (for solids)
Sparingly soluble liquids	$\frac{1}{\text{maximium solubility}}$

Guidance text:

When estimating the vapour pressure for substances in a mixture one needs to account for the fact that more than one substance will contribute to the overall vapour pressure. This is based on a fundamental thermodynamic relationship called Raoult's law. Raoult's law relates the vapour pressure of the components to their composition in an ideal solution. A correction factor is introduced into Raoult's law so it can be used to find the vapour pressures above non-ideal solutions. This correction factor is called the activity coefficient, γ. It describes how interactions between the components' molecules in solution affect composition (expressed as mole fraction, x_i) and hence the vapour pressure exerted by the components of the mixture. Activity coefficients can be determined experimentally. In addition a computer software tool called UNIFAC is available to estimate the activity coefficients, which can be found at http://www.pvv.org/~randhol/xlunifac/.

The partial vapour pressure of a substance in a mixture $p_{i,mix}$ is obtained from the following equation:

$$p_{i,mix} = \gamma_i \chi_i p_i$$

Where,
γ_i = the activity coefficient of substance i
χ_i = the mol fraction of substance i
p_i = the vapour pressure of the substance at the given temperature

The substance emission potential of volatile substance i (E_i) is calculated by using:
$E_i = p_{i,\,mix} / 30000$ (with $E_i = 1$ if $p_{i,\,mix} > 30000$ Pascal)

4.15.4 Paste, slurry or clearly (soaked) wet powder

Question 102.1:
Is the paste or slurry (potentially) contaminated with powdered material?
Answers:
- Yes -> go to question 102.2
- No -> Warning text if this option is selected: "There is no potential for exposure through inhalation from this source." -> STOP. No further questions.

Question 102.2:
What is the measured dustiness of the powder contamination on the paste or slurry (mg/kg for inhalable fraction)?
Answer:
[Numerical value (0-100000)]. *[Based on the answer, one of the dustiness classes in question 15.3 is selected.]*

Guidance text:

Dustiness may be measured by two methods, the rotating drum test and the continuous single drop test, which is described in detail in CEN EN 15051 (2006). The two test methods do not always rank materials in the same order and users should therefore choose the method that is most appropriate for the material and handling process they wish to simulate.

Question 102.3:
If the dustiness of the powder was not measured: To which dustiness class does the substance belong?
Answer:
Dropdown list with following possibilities:
- Extremely fine and light powder.
- Fine dust.
- Coarse dust.
- Granules, flakes or pellets.
- Firm granules, flakes or pellets.

Descriptions and assigned values of each category are given in the table below:

Classification	**Description**	**Assigned value**	**Indicative dustiness test result (inhalable fraction)**[*]	**Indicative dustiness test result (respirable fraction)**[*]	**Guidance images**
Extremely fine and light powder	A powdered product containing very fine, free flowing, light particles. This category may also contain products with a mixture of very fine particles and large particles or granules. Handling the product in its dry form results in a dust cloud that remains airborne for a long time. The product may be wind swept: e.g., magnesium stearate.	1.0	> 5,000 mg/kg	≥ 500 mg/kg	
Fine dust	A powdered product containing fine particles. This category may also contain products with a mixture of fine particles and large particles or granules. Handling the product in its dry form results in a dust cloud that is clearly visible for some time: e.g., talcum powder, carbon black.	0.3	2,000 – 5,000 mg/kg	150 mg/kg	
Coarse dust	A powdered product containing coarse particles. Handling the product in its dry form results in a dust cloud that settles quickly due to gravity: e.g. sand.	0.1	501 - 2,000 mg/kg	50 mg/kg	
Granules, flakes or pellets	Granules or flakes may fall apart and crumble, resulting in only a very limited amount of fine particles. Handling the product does not result in a visible dust cloud; e.g., fertilizer, garden peat, animal pellets.	0.03	101 – 500 mg/kg	15 mg/kg	
Firm granules, flakes or pellets	Product does not result in dust emission without intentional breakage of products: e.g., firm polymer granules, granules covered with a layer of wax, a woodblock, a brick)	0.01	≤ 100 mg/kg	≤ 5 mg/kg	

Question 102.4:

What is the weight fraction of the substance in the powdered contamination on the paste or slurry? If the weight fraction of the substance in the material is not precisely known, pick one of the categories below.

Answer:

<Numeric field> or alternatively dropdown list with following possibilities:

- Pure material (100%)
- Main component (50 – 90 %)
- Substantial (10 – 50 %)
- Minor (5 – 10 %)
- Small (1 – 5 %)
- Very small (0.5 – 1 %)
- Extremely small (0.1 – 0.5 %)
- Minute (0.01 – 0.1 %)
- Extremely minute (< 0.01 %)

If one of the above categories is selected, use the median from the table below in calculating the substance emission potential (E).

		Weight fractions	
Weight fraction categories	**Minimum**	**Median**	**Maximum**
Pure material	1	1	1
Main component	0.5	0.7	0.9
Substantial	0.1	0.3	0.5
Minor	0.05	0.075	0.1
Small	0.01	0.03	0.05
Very small	0.005	0.0075	0.01
Extremely small	0.001	0.003	0.005
Minute	0.0001	0.00055	0.001
Extremely minute	0	0.00005	0.0001

E_{paste} = Dustiness * (median) weight fraction

4.15.5 Powders dissolved in a liquid or incorporated in a liquid matrix

Question 102.5.1:

What is the weight fraction of the powdered substance in the liquid mixture? If the weight fraction of the substance in the liquid mixture is not precisely known, pick one of the categories below.

Answer:

<Numeric field ($0.0 \leq$weight fraction≤ 1.0) > or alternatively dropdown list with following possibilities:

- Main component (50 – 90 %)
- Substantial (10 – 50 %)
- Minor (5 – 10 %)
- Small (1 – 5 %)
- Very small (0.5 – 1 %)
- Extremely small (0.1 – 0.5 %)
- Minute (0.01 – 0.1 %)

If one of the above categories is selected, use the median from the table below in calculating the substance emission potential (E).

	Mole or weight fractions		
Mole/weight fraction categories	**Minimum**	**Median**	**Maximum**
Main component	0.5	0.7	0.9
Substantial	0.1	0.3	0.5
Minor	0.05	0.075	0.1
Small	0.01	0.03	0.05
Very small	0.005	0.0075	0.01
Extremely small	0.001	0.003	0.005
Minute	0.0001	0.0006	0.001

Question 102.5.2:
What is the viscosity of the powder/liquid mixture?
Answer:
Dropdown list with following possibilities:

- Liquids with low viscosity (like water)
- Liquids with medium viscosity (like oil)

Descriptions and assigned values of each category are given in the table below:

Classification	**Assigned value**
Liquids with low viscosity (like water)	1.0
Liquids with medium viscosity (like oil)	0.3

The substance emission potential of powder i dissolved in liquid (E_i) is calculated by using:
*E_i = (10/30000) * (median) mol fraction * viscosity.*

Go to question 103

4.15.6 Hot or molten metal

Question 102.6:
What is the weight fraction of the metal of interest in the molten metal mixture? If the weight fraction of the metal of interest in the molten metal mixture is not precisely known, pick one of the categories below.
Answer:
<Numeric field (0.0≤weight fraction≤1.0) > or alternatively dropdown list with following possibilities:

- Pure material (100%)
- Main component (50 – 90 %)
- Substantial (10 – 50 %)
- Minor (5 – 10 %)
- Small (1 – 5 %)
- Very small (< 1 %)

If one of the above categories is selected, use the median from the table below in calculating the substance emission potential (E).

	Mole or weight fractions		
Mole/weight fraction categories	**Minimum**	**Median**	**Maximum**

Pure material	1	1	1
Main component	0.5	0.7	0.9
Substantial	0.1	0.3	0.5
Minor	0.05	0.075	0.1
Small	0.01	0.03	0.05
Very small	0	0.005	0.01

Question 102.7:
What is the process temperature of the molten metal mixture (in Celsius)?
Answer:
<Numeric field>

Question 102.8:
What is the melting point temperature of the metal of interest (in Celsius)?
Answer:
<Numeric field>

The weighting of the temperature of the molten metal mixture in relation to the melting point of the metal of interest is derived from the table below:

Tmixture/MPt metal of interest	Examples	Weighting
> 2.5	$T_{mixture}$ = 1600 ^{o}C MPt metal A = 600 ^{o}C	3
1.5 - 2.5	$T_{mixture}$ = 1000 ^{o}C MPt metal A = 500 ^{o}C	2
< 1.5	$T_{mixture}$ = 625 ^{o}C MPt metal A = 500 ^{o}C	1

The substance emission potential of molten metal i in molten metal mixture (E_i) is calculated by using:
*E_i = (median) weight fraction * temperature weighting*

Go to question 103

4.16 Activity emission potential (FF source)

[By default the answers from the NF activity emission potential apply]

Question 103:
To which activity class does your activity belong?
Answer:
Dropdown list with following possibilities:

[Based on the product type selected in question 3, the activity classes marked with a '+' in the table below should appear in the dropdown list.]

Activity class	Description [given by mouse-over]	Applies for "solid objects"	Applies for Powdered, granular and pelletized material	Applies for liquids and powders dissolved in a liquid	Applies for paste, slurry or clearly wet powder	Applies for hot or molten metals

Fracturing and abrasion of solid objects	Activities where solid objects are broken into smaller parts or are abraded due to frictional forces.	+	-	-	-	-
Abrasive blasting	A surface preparation technique for removing coatings or contamination by propelling abrasive material towards the surface at high velocity. ART only considers exposure arising from the surface coatings during abrasive blasting (i.e., exposure to the abrasive material is not included)	+	-	-	-	-
Impaction on contaminated solid objects	Activities where impaction or striking of a tool on an object contaminated with powder or granules potentially results in re-suspension of that powder. For this activity class, exposure is estimated to be related to the level of contamination on the surface or the object that is impacted on.	-	+	-	-	-
Handling of contaminated solid objects or paste	Handling or transport of surfaces, objects or pastes that are (potentially) contaminated with powders or granules. For this activity class, exposure is estimated to the contamination on the surface, object or paste.	-	+	-	+	-
Spray application of powders	Activities where movement and agitation of powders results in disturbances of the product causing dust particles to become airborne.	-	+	-	-	-
Movement and agitation of powders, granules or pelletized material	Activities where a stream of powder is transferred from one reservoir (or container, vessel) to the receiving vessel. The product may either fall due to gravity from a high to a lower point (dumping of powders), be transferred horizontally (scooping of powders) or is transferred through a hose or tube with pressure (vacuum transfer).	-	+	-	-	-
Transfer of powders, granules or pelletized material	Activities where powders, granules or pelletized material are compressed due to compaction or crushing.	-	+	-	-	-
Compressing of powders, granules or pelletized material	Activities where powders, granules or pelletized material are crushed and broken into smaller parts or sizes due to frictional forces (e.g. between two surfaces or objects)	-	+	-	-	-
Fracturing of powders, granules or pelletized material	Activities used to atomise liquids into droplets for dispersion on surfaces	-	+	-	-	-

	(surface spraying) or into air (space spraying). Spraying techniques may be used for dispersion of e.g. pesticides, biocides, and paints.					
Spray application of liquids	Handling of a liquid product in a bath or other reservoir. The liquid may either be relatively undisturbed (e.g. manual stirring, dipping in bath) or agitated (e.g. gas bubbling, mechanical mixing in vessel).	-	-	+	-	-
Activities with open liquid surfaces		-	-	+	-	-
Handling of contaminated objects	Activities where a liquid product is directly spread on surfaces using e.g. a roller, brush or wipe.	-	-	+	-	-
Spreading of liquid products	High energy activities with e.g. rotating tools where liquids are added to the process (e.g. metal working fluids).	-	-	+	-	-
Application of liquids in high speed processes		-	-	+	-	-
Transfer of liquid products		-	-	+	-	+
Burning of liquids [*This is outside the applicability domain of the beta version. Should be visible but not selectable]*		-	-	+	-	+
Smelting and melting of metal		-	-	-	-	+
Pouring or tapping of molten metal (including melt drossing and dipping in molten metal)		-	-	-	-	+
Sintering, roasting and oxidation / burning		-	-	-	-	+
Spray application of molten metal		-	-	-	-	+
Atomisation		-	-	-	-	+
Compressing of, impaction on, or hardening of hot metal objects		-	-	-	-	+

See table below for combination of activity classes and subclasses with example activities. Show the example activities with the dropdown lists above (mouse-over function).

Activity class	**Activity subclass**	**Example activities**
Fracturing and abrasion of solid objects		• Crushing concrete • Jack hammering • Pulverizing • Sawing using a circular saw • (Manual) milling • Sanding • (Cut-off) grinding of steel • Drilling • Buffing

		• Polishing • Chiselling • Cutting • Logging • Demolishing with wrecking ball • Wrecking • Shredding of batteries • Wire drawing • Cold rolling of metal sheets
Abrasive blasting		• Grit blasting • (Ultra) high pressure blasting for stripping paint • Water cutting
Impaction on contaminated solid objects		• Hammering • Nailing • Piling • Punching
Handling of contaminated solid objects or paste		• Sorting • Stacking • Carrying • Picking / collecting objects • Packaging • Paving • Wrapping • Disposal of empty bags • Plastering • Kneading • Modelling of product • Bending metal tubes
Spray application of powders		• Dusting crops • Powder coating • Spraying of concrete
Movement and agitation of powders, granules or pelletized material		• Sweeping • Application of compressed air • Vacuum cleaning • Mixing • Weighing • Raking • Sieving
Transfer of powders, granules or pelletized material	Falling of powders, granules or pelletized material	• Bagging solids • Dumping solids in mixers • Loading barges with minerals or cereals • Scooping • Scattering • Filling of bottles
	Vacuum transfer of powders, granules or pelletized material	• *[picture vacuum transfer]*
Compressing of powders, granules or pelletized material		• (steam)Rolling • Compacting • Tabletting • Granulation • Pelletization
Fracturing of powders, granules or pelletized material		• Grinding minerals • Milling cereals • Very small scale crushing • Testing tablets • De-lumping (breaking up products) • Large scale bulk milling
Spray application of liquids	Surface spraying of liquids	• Spray application of paints on e.g. ships (using HVLP or airless techniques) • Pest control operations (using backpack) • Spraying cleaning agents onto surfaces • Foaming • Tractor mounted spraying
	Spraying of liquids in a space	• Spraying room deodorizers or fragrances • Fogging • Fly spray
Activities with open liquid surfaces or open reservoirs	Activities with relatively undisturbed surfaces (no aerosol formation)	• Dipping objects in a cleaning bath (where the presence of treated surfaces in the area is limited)

		• Immersion of objects • Manual stirring of paint • Tank dipping
	Activities with agitated surfaces	• Electroplating • Bath with gas bubbling • Mechanical mixing / blending of paint • Aeration of waste water • Boiling • Shaking liquids (e.g. in chemical laboratories)
Handling of contaminated objects		• Heat drying tasks • Evaporation from painted surface or object • Maintenance of fuel pumps • Coupling and decoupling of hoses or (drilling) equipment • Handling of contaminated tools
Spreading of liquid products		• Painting a ceiling and walls with a roller and a brush • Hand lay-up activities with styrene • Pouring a liquid flooring material on a floor • Cleaning of liquid spills • Gluing • Mopping • Embalming • Laminating • Lubricating • Sponging • Screen printing • Cleaning of oil residue from bulk tanks
Application of liquids in high speed processes (e.g. rotating tools)		• Use of metal working fluids with e.g. circular saws and drills • Centrifuging wet items • Press printing
Transfer of liquid products	Bottom loading	• Bottom loading of tanker at bulk terminal • Under wing refuelling of aircraft • Transfer of additives in tanker using bottom loading
	Falling liquids	• Top loading of tanker at bulk terminal (boats, rail car or truck) • Filling of drums • Pouring • Filling of bottles • Filling of paint gun • Refuelling of cars • Manual calibration of fuel pump • Over wing refuelling of aircraft
Smelting and melting of metal	Smelting of metal	
	Melting of metal	
Pouring or tapping of molten metal (including melt drossing and dipping in molten metal)	Pouring or tapping of molten metal	
	Dipping in molten metal	
Sintering, roasting and oxidation / burning	Sintering	
	Roasting	
	Oxidation or burning	
Spray application of molten metal		
Atomisation		
Compressing of, impaction on, or hardening of hot metal objects		• Quenching • Hot rolling • Metal cladding • Hot forging

Guidance text:

Use the left-hand panel to select the activity class that best fits this emission source.
In some cases an activity class has several subclasses. Use the drop-down list in the right-hand

panel to narrow down your selection.
For each activity class/subclass you will be shown several activities typical for the selected class.

In the next paragraphs, each of the activity (sub)classes is further defined. Based on the choice in the dropdown list above go to the relevant section below.

4.16.1 Fracturing and abrasion of solid objects

Question 104:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

Wood:
- Mechanical sanding of wood resulting in large amounts of dust
- Mechanical handling of wood resulting in large amounts of dust (e.g., large speed of moving work pieces or rotating cutting blades)
- Mechanical handling of wood resulting in limited amount of dust
- Manual handling of wood resulting in limited amount of dust
- Manual handling of wood resulting in very limited amount of dust

Stone
- Mechanical pulverization of large amounts of stone or large objects
- Mechanical treatment / abrasion of large surfaces
- Mechanical treatment / abrasion of small sized surfaces
- Mechanical pulverization of stones
- Manual pulverization or treatment / abrasion of small sized objects
- Careful breaking stones

Metal
- Mechanical abrasion or fracturing of metal resulting in small amount of dust
- Mechanical abrasion or fracturing of metal resulting in very limited amount of dust
- Mechanical deforming of metal

Classes and related exposure weights representing emission potential for fracturing and abrasion of wood.

Description	**Examples**	**Exposure weights**
Mechanical sanding of wood resulting in large amounts of dust	belt sanding, handheld sanding machine	30
Mechanical handling of wood resulting in large amounts of dust (e.g., large speed of moving work pieces or rotating cutting blades)	milling operations, lathe, circular saw	10
Mechanical handling of wood resulting in limited amount of dust	planer, chainsaw, shredder, drilling of holes	3
Manual handling of wood resulting in limited amount of dust	manual sawing or sanding	3
Manual handling of wood resulting in very limited amount of dust	screw setting, manual planing	0.3

Classes and related exposure weights representing emission potential for fracturing and abrasion of stone.

Description	Examples	Exposure weights
Mechanical pulverization of large amounts of stone or large objects	Stone crushing machines, demolition using explosives, using a jack hammer to demolish large surfaces, demolition using a crane	100
Mechanical treatment / abrasion of large surfaces	surface grinding, smoothing of concrete walls and floors, cutting concrete blocks using masonry saw	100
Mechanical treatment / abrasion of small sized surfaces	using hand-held grinders to remove mortar	30
Mechanical pulverization of stones	using power tools like jack hammers to demolish small surfaces, recess millers	10
Manual pulverization or treatment / abrasion of small sized objects	use of non-powered tools like hammer or chisel, manual polishing	3
Careful breaking stones	mechanical tile breaking	0.3

Question 104.6:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classes and related exposure weights representing emission potential for containment during fracturing and abrasion of wood.

Classification	Examples	Assigned value
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosed cover on a circular saw (relatively small openings are possible)	0.3

Classes and related exposure weights representing emission potential for containment during fracturing and abrasion of stone.

Classification	Examples	Assigned value
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosed stone crushing machine (relatively small openings are possible)	0.3

Classes and related exposure weights representing process containment during fracturing and abrasion of metal objects.

Classification	Examples	Exposure weights
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosed cover on a battery shredding process	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.
Select 'open process' here if the localized control 'containment without extraction' or 'glove boxes/bags' will be selected in the subsequent question on localized controls.

4.16.2 Abrasive blasting

Question 105:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Abrasive blasting of very large surfaces
- Abrasive blasting of large surfaces
- Abrasive blasting of small parts
- Micro-abrasive blasting

Exposure weights for activity emission potential of Activity Class 'abrasive blasting'.

Description	Example	Exposure weight
Abrasive blasting of very large surfaces	Removing (anti-fouling) paint from ships or bridges. Abrasive blasting is powered by compressed air.	100
Abrasive blasting of large surfaces	Blasting of e.g. car bodies, trailer frames	30
Abrasive blasting of small parts	Blast cleaning of small statues, bicycle frame parts	10
Micro-abrasive blasting	Small-scale abrasive blasting process in e.g. medical aids (blasting area of about a few cm).	1

Question 105.3:
What is the type of abrasive blasting technique?
Answer:

- Dry abrasive blasting
- Wet abrasive blasting

Exposure weights for the type of abrasive blasting technique.

Description	Example	Exposure weight

Dry abrasive blasting	Abrasive blasting is powered by compressed air.	1
Wet abrasive blasting	Includes systems where a mixture of abrasive and water is propelled by compressed air, where water is added to abrasive blasting nozzle, or water jet stripping systems.	0.3

Question 105.5:
What is the direction of abrasive blasting?
Answer:

- Abrasive blasting in any direction (including upwards)
- Only horizontal or downward blasting
- Only downward blasting

Exposure weights for abrasive blasting direction during the activity emission potential of Activity Class ‘abrasive blasting’.

Description	**Exposure weight**
Abrasive blasting in any direction (including upwards)	3
Only horizontal and downward blasting	1
Only downward blasting	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.

For this activity class, exposure is estimated to the solid material (or any liquid in or on the surface of the solid matrix) that is being abraded.

The categories are in rank order with activities generating highest emission levels at the top.

4.16.3 Impaction on contaminated solid objects

Question 106:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Impaction on substantially and visibly contaminated objects (layers of more than 0.5 kg).
- Impaction on objects with visible residual dust
- Impaction on objects with limited visible residual dust
- Impaction on slightly contaminated (layers of less than few grams) objects
- Impaction on apparently clean objects

Classes and related exposure weights for activity emission potential of Activity Class ‘Impaction on contaminated solid object’

Description	**Examples**	**Exposure weight**

Impaction on substantially and visibly contaminated objects (layers of more than 0.5 kg).	Impaction on heavily contaminated filters	3
Impaction on objects with visible residual dust	Hammering on contaminated objects	1
Impaction on objects with limited visible residual dust	Impaction on limited contaminated drums or transfer line.	0.3
Impaction on slightly contaminated objects (layers of less than few grams)	Impaction on objects after closed filling operations.	0.1
Impaction on apparently clean objects	Impaction on drums coming out of a cleaning machine	0.001

Question 106.5:
What is the type of handling?
Answer:
Dropdown list with following possibilities:

- Heavy mechanical impaction
- Normal impaction (manual or light mechanical)

Classes and related exposure weights for type of handling for activity emission potential of Activity Class ‘Impaction on contaminated solid object’

Description	**Examples**	**Exposure weight**
Heavy mechanical impaction	Hydraulic hammers.	3
Normal impaction (manual or light mechanical)	Manual hammering, beating carpets	1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
For this activity class, exposure is estimated to the contamination on the surface or object that is impacted upon.
The categories are in rank order with activities generating highest emission levels at the top.

4.16.4 Handling of contaminated solid objects or paste

Question 107:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Handling of substantially and visibly contaminated objects (layers of more than 0.5 kg).
- Handling of objects with visible contamination (object covered with fugitive dust from surrounding dusty activities)
- Handling of objects with limited residual dust (thin layer visible)
- Handling of slightly contaminated (layers of less than few grams) objects
- Handling of apparently clean objects

Classes and related exposure weights for activity emission potential of activity subclass ‘Handling of contaminated solid objects or pastes’

Description	**Examples**	**Exposure weight**
Handling of substantially and visibly contaminated objects (layers of more than 0.5 kg).	Stacking cement bags with dust contamination (leakage from bag valve), disposal of empty contaminated bags, disposal of contaminated filters, maintenance of heavily contaminated equipment	1
Handling of objects with visible contamination (object covered with fugitive dust from surrounding dusty activities)	Transport of contaminated wooden objects, carrying contaminated bags, changing contaminated filters	0.3
Handling of objects with limited residual dust (thin layer visible)	Transportation of drums. Coupling/decoupling of transfer line. Transport of contaminated metal objects. Replacing filters.	0.1
Handling of slightly contaminated objects (layers of less than few grams product)	Handling of slightly contaminated glass bottles or plastic kegs. Packaging of objects after closed filling operations.	0.03
Handling of apparently clean objects	Drums coming out of a cleaning machine	0.001

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
For this activity class, exposure is estimated to the contamination on the surface or object.
The categories are in rank order with activities generating highest emission levels at the top.

Question 107.5:
How are contaminated objects or pastes handled?
Answer:
Dropdown list with following possibilities:

- Normal handling, involves regular work procedures.
- Careful handling, involves workers showing attention to potential danger, error or harm and carrying out the activity in a very exact and thorough (or cautious) manner.

Classes and related exposure weights for type of handling.

Description	**Exposure weight**
Handling that departs from regular work procedures and involves large amounts of energy (e.g. rough handling or throwing of bags)	3
Normal handling, involves regular work procedures.	1
Careful handling, involves workers showing attention to potential danger, error or harm and carrying out the activity in a very exact and thorough (or cautious) manner.	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.16.5 Spray application of powders

Question 108:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Powder coating
- Dusting using blower

Classes and related exposure weights for activity emission potential of Activity Class 'spray application of powders'.

Description	**Example**	**Exposure weights**
Powder coating	Powder spraying using electrostatic spray gun	10
Dusting using blower	Dusting crops with knapsack dust blower	3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Question 108.5:
What is the spray direction?
Answer:

- Spraying in any direction (including upwards)
- Only horizontal or downward spraying
- Only downward spraying

Classes and related exposure weights for spray direction.

Description	**Exposure weights**
Spraying in any direction (including upwards)	3
Only horizontal or downward spraying	1
Only downward spraying	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.16.6 Movement and agitation of powders, granules or pelletized material

Question 109:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:
- Movement and agitation of 1000 kg or more
- Movement and agitation of 100 - 1000 kg
- Movement and agitation of 10 - 100 kg
- Movement and agitation of 1 - 10 kg
- Movement and agitation of 0.1 - 1 kg
- Movement and agitation of 10 - 100 gram
- Movement and agitation of < 10 gram

Classes and related exposure weights for activity emission potential of Activity Class ‘movement and agitation of powders, granules or pelletized material’

Description	**Example activities**	**Exposure weight**
Movement and agitation of 1000 kg or more	Sieving big bag volumes in large production plants (e.g. sieving peat moss)	30
Movement and agitation of 100 - 1000 kg	Cleaning large heaps of dust or debris (after demolition) Sieving, mixing or blending in vessels	10
Movement and agitation of 10 - 100 kg	Cleaning heavily contaminated floors (e.g. after dusty activities like bagging or abrasion) Sieving, mixing or blending in large buckets	3
Movement and agitation of 1 - 10 kg	Cleaning floors (sweeping) covered with fugitive dust Manual sieving, mixing or blending	1
Movement and agitation of 0.1 - 1 kg	Using brush and dustpan to clean up small spills Manual sieving, mixing or blending	0.3
Movement and agitation of 10 - 100 gram	Using brush and dustpan to clean up small spills Manual sieving, mixing or blending	0.1
Movement and agitation of < 10 gram	Cleaning valves/machinery/equipment with wipe Mixing on laboratory scale	0.03

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Question 109.5:
What is the handling type?
Answer:
Dropdown list with following possibilities:
- Application of compressed air
- Other handling with high level of agitation

- Handling with low level of agitation

Classes and related exposure weights for type of handling

Description	Examples	Exposure weight
Application of compressed air	Using compressed air to clean e.g. machines	30
Other handling with high level of agitation	Sweeping of floors, sieving, mechanical mixing	3
Handling with low level of agitation	Manual mixing	1

Question 109.7:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	Examples	Exposure weight
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Contained sieving of big bags with only small opening	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.
Select 'open process' here if the localized control 'containment without extraction' or 'glove boxes/bags' will be selected in the subsequent question on localized controls.

4.16.7 Transfer of powders, granules or pelletized material

4.16.7.1 Falling powders

Question 110:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Transferring more than 1000 kg/minute
- Transferring 100 – 1000 kg/minute
- Transferring 10 – 100 kg/minute
- Transferring 1 – 10 kg/minute

- Transferring 0.1 – 1 kg/minute
- Transferring 10 – 100 gram/minute
- Transferring less than 10 gram/minute

Classes and related exposure weights for activity emission potential of Activity Class ‘Falling of powdered, granular or pelletized material’.

Description	Examples	Exposure weights
Transferring more than 1000 kg/minute	Large scale transfer with big bags	30
Transferring 100 – 1000 kg/minute	Automated dumping of powders (e.g. auger or conveyer belt)	10
Transferring 10 – 100 kg/minute	Manual dumping of powders	3
Transferring 1 – 10 kg/minute	Scooping activities	1
Transferring 0.1 – 1 kg/minute	Filling bottles	0.3
Transferring 10 – 100 gram/minute	Small-scale scooping for sampling	0.1
Transferring less than 10 gram/minute	Very small scale weighing (fine adjustments) and scooping in laboratory	0.03

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Question 110.5:

What is the type of handling?

Answer:

Dropdown list with following possibilities:

- Routine transfer
- Careful transfer involves workers showing attention to potential danger, error or harm and carrying out the activity in a very exact and thorough (or cautious) manner, e.g. careful weighing in laboratory.

Exposure weights for type of handling

Description	Exposure weight
Routine transfer	1
Careful transfer involves workers showing attention to potential danger, error or harm and carrying out the activity in a very exact and thorough (or cautious) manner, e.g. careful weighing in laboratory	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Question 110.7:

What is the drop height?
Answer:
Dropdown list with following possibilities:
- Drop height > 0.5 m
- Drop height < 0.5 m

Exposure weights for drop height

Description	**Exposure weight**
Drop height > 0.5 m	3
Drop height < 0.5 m	1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The drop height is measured from the bottom of the dumping opening to the top of the receiving object or surface.

Question 110.8:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:
- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	**Examples**	**Exposure weight**
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Dumping powders in a big bag through a small dumping opening	0.3

4.16.7.2 Vacuum transfer of powders

Question 110.9.1:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:
- Transferring more than 1000 kg/minute
- Transferring 100 – 1000 kg/minute
- Transferring 10 – 100 kg/minute
- Transferring 1 – 10 kg/minute
- Transferring 0.1 – 1 kg/minute
- Transferring 10 – 100 gram/minute
- Transferring less than 10 gram/minute

Classes and related exposure weights for activity emission potential of sub Activity Class ‘Vacuum transfer of powders’.

Description	Examples	Exposure weights
Transferring more than 1000 kg/minute	Large scale vacuum transfer from large vessels	3
Transferring 100 – 1000 kg/minute		1
Transferring 10 – 100 kg/minute		0.3
Transferring 1 – 10 kg/minute		0.1
Transferring 0.1 – 1 kg/minute		0.03
Transferring 10 – 100 gram/minute		0.01
Transferring less than 10 gram/minute	Micro powder transfer systems	0.003

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Question 110.9.2:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classes and related exposure weights representing process containment during vacuum transfer of powders, granules or pelletized material

Classification	Examples	Exposure weights
Open process	Vacuum transfer from open reservoir to enclosed reservoir	1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Vacuum transfer from reservoir with small opening to enclosed reservoir	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.
Select 'open process' here if the localized control 'containment without extraction' or 'glove boxes/bags' will be selected in the subsequent question on localized controls.

4.16.8 Compressing of powders, granules or pelletized material

Question 111:
Which of the situations below does best represent your activity?

Answer:

Dropdown list with following possibilities:

- Compressing more than 1000 kg/minute
- Compressing 100 – 1000 kg/minute
- Compressing 10 – 100 kg/minute
- Compressing 1 – 10 kg/minute
- Compressing 0.1 – 1 kg/minute
- Compressing 10 – 100 gram/minute
- Compressing less than 10 gram/minute

Classes and related exposure weights for activity emission potential of Activity Class ‘Compressing of powders, granules or pelletized material’

Description	**Examples**	**Exposure weights**
Compressing more than 1000 kg/minute	Large scale bulk compression of soil or wood pellets	30
Compressing 100 – 1000 kg/minute		10
Compressing 10 – 100 kg/minute		3
Compressing 1 – 10 kg/minute		1
Compressing 0.1 – 1 kg/minute		0.3
Compressing 10 – 100 gram/minute		0.1
Compressing less than 10 gram/minute	Very small scale tabletting, granulation	0.03

Question 111.3:

What is the level of containment of the process?

Answer:

Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	**Examples**	**Exposure weight**
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosed tabletting machine (relatively small openings are possible)	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.
Select ‘open process’ here if the localized control ‘containment without extraction’ or ‘glove boxes/bags’ will be selected in the subsequent question on localized controls.

4.16.9 Fracturing of powders, granules or pelletized material

[Note: when this activity class is selected, the dustiness category (Question 92) should be overruled and set to 'fine dust' (assigned value = 0.3)]

Question 111.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Fracturing more than 1000 kg/minute
- Fracturing 100 – 1000 kg/minute
- Fracturing 10 – 100 kg/minute
- Fracturing 1 – 10 kg/minute
- Fracturing 0.1 – 1 kg/minute
- Fracturing 10 – 100 gram/minute
- Fracturing less than 10 gram/minute

Description	Examples	Exposure weights
Fracturing more than 1000 kg/minute	Large scale bulk milling	30
Fracturing 100 – 1000 kg/minute		10
Fracturing 10 – 100 kg/minute		3
Fracturing 1 – 10 kg/minute		1
Fracturing 0.1 – 1 gram/minute		0.3
Fracturing 10 – 100 gram/minute		0.1
Fracturing less than 10 gram/minute	Very small scale crushing / testing tablets, de-lumping (breaking up products)	0.03

Question 111.8:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	Examples	Exposure weight
Open process		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosed tablet crushing (relatively small openings are possible)	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.
Select 'open process' here if the localized control 'containment without extraction' or 'glove boxes/bags' will be selected in the subsequent question on localized controls.

4.16.10 Spray application of liquids

4.16.10.1 Surface spraying of liquids

Question 112:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:
- High application rate (> 3 l/minute)
- Moderate application rate (0.3 - 3 l/minute)
- Low application rate (0.03 – 0.3 l/minute)
- Very low application rate (< 0.03 l/minute)

Classes and related exposure weights for activity emission potential of Activity Subclass 'surface spraying of liquids'.

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
High application rate (> 3 l/minute)	Tractor mounted spraying	3	3
Moderate application rate (0.3 - 3 l/minute)	Paint spraying of e.g. ships	1	1
Low application rate (0.03 – 0.3 l/minute)	Pest control operations	0.3	0.3
Very low application rate (< 0.03 l/minute)	Spot spraying using e.g. controlled droplet application	0.1	0.1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
This activity class includes the spraying of liquids onto surfaces or objects (e.g. paint spraying).
The categories are in rank order with activities generating highest emission levels at the top.

Question 112.5:
What is the spray direction?
Answer:
- Spraying in any direction (including upwards)
- Only horizontal or downward spraying
- Only downward spraying

Classes and related exposure weights for spray direction.

Description	Aerosol exposure weights (incl. powders dissolved in a liquid)	Vapour exposure weights
Spraying in any direction (including upwards)	3	3
Only horizontal or downward spraying	1	1
Only downward spraying	0.3	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.

Question 112.7:
What is the spray technique?
Answer:
- Spraying with high compressed air use
- Spraying with no or low compressed air use

Classes and exposure weights for spray technique

Description	Examples	Aerosol exposure weights (incl. powders dissolved in a liquid)	Vapour exposure weights
Spraying with high compressed air use	Air blast pesticide spraying of e.g. tree nursery	3	3
Spraying with no or low compressed air use	Paint spraying using HVLP or airless techniques; pest control operations using backpack	1	1

4.16.10.2 Spraying of liquids in a space

Question 113:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:
- Large scale space spraying
- Small scale space spraying

Classes and related exposure weights for spraying of liquids in a space.

Description	Examples	Aerosol exposure weights (incl. powders dissolved in a liquid)	Vapour exposure weight
Large scale space spraying	Fogging	30	30
Small scale space spraying	Fly spray	3	3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
This activity class includes the spraying of liquids into an open space (e.g. fogging or fly spray).
The categories are in rank order with activities generating highest emission levels at the top.

4.16.11 Activities with open liquid surfaces and open reservoirs

4.16.11.1 Activities with relatively undisturbed surfaces (no aerosol formation)

Question 114:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Open surface > 3 m^2
- Open surface 1 - 3 m^2
- Open surface 0.3 - 1 m^2
- Open surface 0.1 – 0.3 m^2
- Open surface < 0.1 m^2

Classes and related exposure weights for activity emission potential of Activity Subclass ‘Activities with (evaporating) bath’

Description	Examples	Aerosol exposure weights (incl. powders dissolved in a liquid)	Vapour exposure weights
Open surface > 3 m^2	Tank dipping	0.001	0.3
Open surface 1 - 3 m^2		0.001	0.1
Open surface 0.3 - 1 m^2		0.001	0.03
Open surface 0.1 – 0.3 m^2		0.001	0.01

Open surface < 0.1 m^2	Manual stirring in paint can Storage of laboratory samples	0.001	0.003

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.16.11.2 Activities with agitated surfaces

Question 114.3:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Open surface > 3 m^2
- Open surface 1 - 3 m^2
- Open surface 0.3 - 1 m^2
- Open surface 0.1 – 0.3 m^2
- Open surface < 0.1 m^2

Classes and related exposure weights for surface area

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Open surface > 3 m^2	Bath with gas bubbling (e.g. electroplating) Bath with ultrasonic cleaning	0.3	1.0
Open surface 1 - 3 m^2		0.1	0.3
Open surface 0.3 - 1 m^2		0.03	0.1
Open surface 0.1 – 0.3 m^2		0.01	0.03
Open surface < 0.1 m^2	Mechanical mixing in paint can, mechanical mixing very small amounts in e.g. laboratory	0.003	0.01

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.16.12 Handling of contaminated objects

Question 114.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Activities with treated/contaminated objects (surface > 3 m2)
- Activities with treated/contaminated objects (surface 1-3 m2)
- Activities with treated/contaminated objects (surface 0.3-1 m2)
- Activities with treated/contaminated objects (surface 0.1-0.3 m2)
- Activities with treated/contaminated objects (surface <0.1 m2)

Classes and related exposure weights for activity emission potential of Activity Subclass 'handling of contaminated objects'

Description		**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Activities with treated/contaminated objects (surface > 3 m^2)	Handling large treated and drying objects	0.001	0.3
Activities with treated/contaminated objects (surface 1-3 m^2)	Maintenance of fuel pumps; coupling and decoupling of hoses or (drilling) equipment	0.001	0.1
Activities with treated/contaminated objects (surface 0.3-1 m^2)	Handling small treated and drying objects	0.001	0.03
Activities with treated/contaminated objects (surface 0.1-0.3 m^2)	Handling of contaminated tools	0.001	0.01
Activities with treated/contaminated objects (surface <0.1 m^2)	Handling small tools in laboratory (e.g. pipettes)	0.001	0.003

Question 114.7:
What is the level of contamination of the surface of the objects?
Answer:
Dropdown list with following possibilities:

- Contamination > 90 % of surface
- Contamination 10-90 % of surface
- Contamination < 10 % surface

Classes and related exposure weights for level of contamination of objects

Description	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**

Contamination > 90 % of surface	1	1
Contamination 10-90 % of surface	0.3	0.3
Contamination < 10 % surface	0.1	0.1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.16.12.1 Spreading of liquid products

Question 115:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Spreading of liquids at surfaces or work pieces > 3 m2 / hour

- Spreading of liquids at surfaces or work pieces 1.0 - 3.0 m2 / hour
- Spreading of liquids at surfaces or work pieces 0.3 - 1.0 m2 / hour
- Spreading of liquids at surfaces or work pieces 0.1 - 0.3 m2 / hour
- Spreading of liquids at surfaces or work pieces < 0.1 m2 / hour

Classes and related exposure weights for activity emission potential of Activity Subclass ‘Spreading of liquid products’

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Spreading of liquids at surfaces or work pieces > 3 m^2 / hour	Painting of walls or ships, removing (large) graffiti, cleaning of oil residue from bulk tanks	0.1	0.3
Spreading of liquids at surfaces or work pieces 1.0 - 3.0 m^2 / hour	Degreasing machines, painting of walls	0.1	0.1
Spreading of liquids at surfaces or work pieces 0.3 - 1.0 m^2 / hour	Painting of casings using a roller or brush, gluing e.g. shoe soles, degreasing or cleaning small machines/tools	0.1	0.03
Spreading of liquids at surfaces or work pieces 0.1 - 0.3 m^2 / hour	Spot degreasing (small objects like knifes), gluing stickers and labels	0.01	0.01
Spreading of liquids at surfaces or work pieces < 0.1 m^2 / hour	Small scale spreading e.g. in laboratory	0.001	0.003

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.16.13 Application of liquids in high speed processes (e.g. rotating tools)

Question 116:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large-scale activities involving high speed movements
- Small-scale activities involving high speed movements

Classes and related exposure weights representing emission potential for high speed processes.

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weight**
Large-scale activities involving high speed movements	Rotating pipes in oil drilling, rotating press during printing, application of metal working fluids in machining large work pieces	3	3
Small-scale activities involving high speed movements	Application of MWF in machining of small scale work pieces (e.g. < 10 kg)	1	1

Question 116.5:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process: no separation between process and worker
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	**Examples**	**Exposure weight**
Open process: no separation between process and worker		1.0
Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).	Enclosing panels around machining process	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

Select ‘open process’ here if the localized control ‘containment without extraction’ or ‘glove boxes/bags’ will be selected in the subsequent question on localized controls.

4.16.14 Transfer of liquid products

4.16.14.1 Bottom loading

Question 118:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Transfer of liquid product with flow of > 1000 l/minute
- Transfer of liquid product with flow of 100 - 1000 l/minute
- Transfer of liquid product with flow of 10 - 100 l/minute
- Transfer of liquid product with flow of 1 - 10 l/minute
- Transfer of liquid product with flow of 0.1 - 1 l/minute
- Transfer of liquid product with flow of < 0.1 l/minute

Classes and related exposure weights for activity emission potential of Activity Class ‘falling liquids’.

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Transfer of liquid product with flow of > 1000 l/minute	Loading of tanker at bulk terminal (boats, rail car or truck)	0.001	0.1
Transfer of liquid product with flow of 100 - 1000 l/minute	Loading of aircraft (under wing)	0.001	0.03
Transfer of liquid product with flow of 10 - 100 l/minute	Transfer of additives in tanker	0.001	0.01
Transfer of liquid product with flow of 1 - 10 l/minute	Transfer of additives in tanker	0.001	0.003
Transfer of liquid product with flow of 0.1 - 1 l/minute	Transfer of additives in tanker	0.001	0.001
Transfer of liquid product with flow of < 0.1 l/minute	Transfer of additives in tanker	0.001	0.001

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.16.14.2 Falling liquids

Question 119:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Transfer of liquid product with flow of > 1000 l/minute
- Transfer of liquid product with flow of 100 - 1000 l/minute
- Transfer of liquid product with flow of 10 - 100 l/minute
- Transfer of liquid product with flow of 1 - 10 l/minute
- Transfer of liquid product with flow of 0.1 – 1 l/minute
- Transfer of liquid product with flow of < 0.1 l/minute

Exposure weights for activity emission potential of Activity Class 'falling liquids' in case of splash loading.

Description	**Examples**	**Aerosol exposure weights (incl. powders dissolved in a liquid)**	**Vapour exposure weights**
Transfer of liquid product with flow of > 1000 l/minute	Loading of tanker at bulk terminal (boats, rail car or truck)	0.1	0.1
Transfer of liquid product with flow of 100 - 1000 l/minute	Filling of drums	0.03	0.03
Transfer of liquid product with flow of 10 - 100 l/minute	(Re)fuelling cars, manual topping up, manual calibration of fuel pump	0.01	0.01
Transfer of liquid product with flow of 1 - 10 l/minute	Filling of bottles, filling of paint gun	0.003	0.003
Transfer of liquid product with flow of 0.1 – 1 l/minute	Filling of bottles, filling of paint gun	0.001	0.001
Transfer of liquid product with flow of < 0.1 l/minute	Transfer of small amounts in laboratory	0.001	0.001

Question 119.5:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Open process
- Handling that reduces contact between product and adjacent air. Note: This does not include processes that are fully contained by localized controls (see next questions).

Classification	**Examples**	**Exposure weight**
Open process		1.0
Handling that reduces contact between product and adjacent air.	Transfer of liquid through a small filling opening (e.g. refuelling of vehicles)	0.3

Note: This does not include processes that are fully contained by localized controls (see next questions).

Question 120:
Is the transfer of liquid performed by splash or submerged loading?
Answer:
Dropdown list with following possibilities:

- Splash loading, where the liquid dispenser remains at the top of the reservoir and the liquid splashes freely
- Submerged loading, where the liquid dispenser remains below the fluid level reducing the amount of aerosol formation

Classes and related exposure weights representing submerged and splash loading.

Classification	Exposure weights
Splash loading, where the liquid dispenser remains at the top of the reservoir and the liquid splashes freely	3.0
Submerged loading, where the liquid dispenser remains below the fluid level reducing the amount of aerosol formation	1.0

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.16.15 Smelting or melting of metal

4.16.15.1 Smelting of metal

Question 121:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Smelting in an inherently closed process)

The actual smelting process has to be fully enclosed, including the loading/charging operation, and operators spend most of their time in control rooms during routine operation. This means that exposures are possible only during regular control inspections and tapping, which are part of activity class: “Pouring or tapping of molten metals”.

Classification	Examples	Exposure weight
Smelting in an inherently closed process		0.001

[If this activity subclass is selected, the answer to the localized control question cannot be ‘containment – no extraction’, ‘enclosing hoods’ or ‘glove boxes/bags’.]

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.

The categories are in rank order with activities generating highest emission levels at the top.

4.16.15.2 Melting of metal

Question 121.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large scale melting (> 10 tonnes)
- Medium scale melting (1-10 tonnes)
- Small scale melting (100 – 1000 kg)
- Very small scale melting (< 100 kg)

Classification	**Examples**	**Exposure weight**
Large scale melting (> 10 tonnes)	> 10 tonnes	3
Medium scale melting (1-10 tonnes)	1-10 tonnes	1
Small scale melting (100 – 1000 kg)	100 – 1000 kg	0.3
Very small scale melting (< 100 kg)	< 100 kg	0.1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.16.16 Pouring or tapping of molten metal (including melt drossing and dipping in molten metal)

4.16.16.1 Pouring or tapping of molten metal

Question 122:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large scale pouring or tapping (> 10 tonnes)
- Medium scale pouring or tapping (1-10 tonnes)
- Small scale pouring or tapping (100 – 1000 kg)
- Very small scale pouring or tapping (< 100 kg)

Classification	**Examples**	**Exposure weight**
Large scale pouring or tapping (> 10 tonnes)	> 10 tonnes	10
Medium scale pouring or tapping (1-10 tonnes)	1-10 tonnes	3
Small scale pouring or tapping (100 – 1000 kg)	100 – 1000 kg	1
Very small scale pouring or tapping (< 100 kg)	< 100 kg	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.16.16.2 Dipping in molten metal

Question 122.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Open surface > 3 m2
- Open surface 1 - 3 m2
- Open surface 0.3 - 1 m2
- Open surface 0.1 – 0.3 m2
- Open surface < 0.1 m2

Classification	**Examples**	**Exposure weight**
Open surface > 3 m^2		3
Open surface 1 - 3 m^2		1
Open surface 0.3 - 1 m^2		0.3
Open surface 0.1 – 0.3 m^2		0.1
Open surface < 0.1 m^2		0.03

Question 122.7:
Is a flux used as a protective layer on the molten metal?
Answer:
Dropdown list with following possibilities:

- No use of flux
- Use of flux as protective layer on molten metal

Classification	**Examples**	**Exposure weight**
No use of flux		1
Use of flux as protective layer on molten metal	Fluxed bath	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.16.17 Sintering, roasting, oxidation or burning

4.16.17.1 Sintering

Question 123:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large scale sintering (> 10 tonnes)
- Medium scale sintering (1-10 tonnes)
- Small scale sintering (100 – 1000 kg)
- Very small scale sintering (< 100 kg)

Classification	Examples	Exposure weight
Large scale sintering (> 10 tonnes)	> 10 tonnes	10
Medium scale sintering (1-10 tonnes)	1-10 tonnes	3
Small scale sintering (100 – 1000 kg)	100 – 1000 kg	1
Very small scale sintering (< 100 kg)	< 100 kg	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.16.17.2 Roasting

Question 123.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large scale roasting (> 10 tonnes)
- Medium scale roasting (1-10 tonnes)
- Small scale roasting (100 – 1000 kg)
- Very small scale roasting (< 100 kg)

Classification	Examples	Exposure weight
Large scale roasting (> 10 tonnes)	> 10 tonnes	10
Medium scale roasting (1-10 tonnes)	1-10 tonnes	3
Small scale roasting (100 – 1000 kg)	100 – 1000 kg	1
Very small scale roasting (< 100 kg)	< 100 kg	0.3

Question 123.7:
What is the level of containment of the process?
Answer:
Dropdown list with following possibilities:

- Tunnel oven
- Enclosed roasting furnace

Classification	Examples	Exposure weight
Tunnel oven	Tunnel oven,	1
Enclosed roasting furnace	Rotary kiln	0.001

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.16.17.3 Oxidation, burning

Question 124:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Large scale oxidation, burning (> 10 tonnes)
- Medium scale oxidation, burning (1-10 tonnes)
- Small scale oxidation, burning (100 – 1000 kg)
- Very small scale oxidation, burning (< 100 kg)

Classification	**Examples**	**Exposure weight**
Large scale oxidation, burning (> 10 tonnes)		10
Medium scale oxidation, burning (1-10 tonnes)	Production of speciality products, such as high purity oxides	3
Small scale oxidation, burning (100 – 1000 kg)		1
Very small scale oxidation, burning (< 100 kg)	Rotary furnaces	0.3

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.16.18 Spray application of hot metal

Question 124.5:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Deposition rate > 5 kg/hr
- Deposition rate < 5 kg/hr

Classification	**Examples**	**Exposure weight**
Deposition rate > 5 kg/hr	Detonation gun	0.03
Deposition rate < 5 kg/hr	Plasma spraying	0.01

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.16.19 Atomisation

Question 125:
[There is no question needed here. This is just one class. When this sub activity class is selected, show the following text:
Metallic powders can be obtained by atomisation of a furnace melt (melt atomisation). This can be achieved by a variety of means such as by spraying molten metal under pressure through a nozzle into a variety of media {liquid atomisation (water or oil) or gas atomisation (air, nitrogen or argon) techniques} and by more specialised techniques including centrifugal atomisation {pouring a melt onto a rotating disc or using the Rotating Electrode Process (REP)}, ultrasound and pressure. This process requires full enclosure to achieve atomisation and powder formation.

Classification	**Examples**	**Exposure weight**
Atomisation in enclosed tank		0.001

[If this activity subclass is selected, the answer to the localized control question cannot be 'containment – no extraction', 'enclosing hoods' or 'glove boxes/bags'.]

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.16.20 Compressing of, impacting on, or hardening of metal objects

Question 126:
Which of the situations below does best represent your activity?
Answer:
Dropdown list with following possibilities:

- Mechanical hot forging, hot rolling or quenching of large scale metal objects
- Manual forging, small scale mechanical rolling or quenching of smaller sized hot metal objects

Classification	**Examples**	**Exposure weight**
Mechanical hot forging, hot rolling or quenching of large scale metal objects	Hot rolling of slabs > 5000 kg Hot forging of metal objects that cannot be lifted by hand (> 50 kg)	10
Manual forging, small scale mechanical rolling or quenching of smaller sized hot metal objects	Quenching knives or swords Manual forging (e.g. horse smith using hammer and anvil) Hot rolling of rods < 5000 kg	1

Guidance text:

Use the left-hand panel to select the situation that best fits this activity.
The categories are in rank order with activities generating highest emission levels at the top.

4.17 Localized controls (FF source)

[By default the answers from the NF localized controls apply]

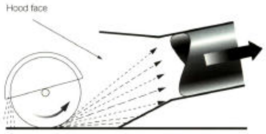
Question 130:
Are there any control measures in close proximity of the far field emission source intended to minimize emissions from the source? *[Warning text: "the control measure should cover the whole activity"]*.
Answer:
Dropdown list with following possibilities:

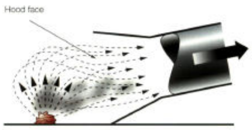
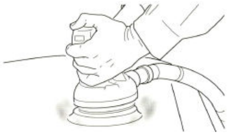
- No localized controls -> go to question 131
- Suppression techniques *[This class should only be visible if the answer to question 90 =* "Powdered, granular or pelletized material" or "Solid objects"] -> *go to separate dropdown list for suppression techniques below*
    - Knockdown suppression
    - Wetting at the point of release
- Containment – no extraction *[If this class is selected the answer to the containment question in the activity emission potential should be overruled and set to 'open process']*
    - Low level containment
    - Medium level containment
    - High level containment
- Local exhaust ventilation (LEV) -> *go to separate dropdown list for LEV below*
    - Receiving hoods -> *go to separate dropdown list for receiving hoods below*
        - Canopy hood
        - Other receiving hoods
    - Capturing hoods -> *go to separate dropdown list for capturing hoods below*
        - Movable capturing hood
        - Fixed capturing hood
        - On-tool extraction
    - Enclosing hoods -> *go to separate dropdown list for enclosing hoods below.*
        - Fume cupboard
        - Horizontal/downward laminar flow booth
        - Other enclosing hoods
    - Other LEV systems
- Glove boxes and glove bags *[If this class is selected the answer to the containment question in the activity emission potential should be overruled and set to 'open process']*
        - Glove bags
            - Glove bags (non-ventilated)
            - Glove bags (ventilated or kept under negative pressure)
        - Glove boxes
            - Low specification glove box
            - Medium specification glove box
            - High specification glove box / isolator
- Vapour recovery systems

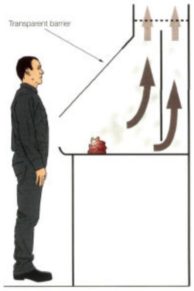
Descriptions and assigned values of each category are given in the table below.

Classification	**Description**	**Assigned typical value**	**Guidance images**
No localized controls	No control measures in close proximity of the source.	1	
Suppression techniques			
Knockdown suppression *[This class should only be visible if the answer to*	Post generation suppression of airborne contaminants to reduce dust levels. Knockdown of a contaminant after it has	0.7	

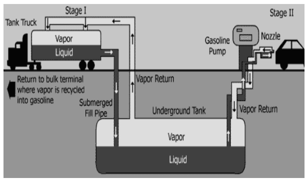
*question 3 = “*Powdered, granular or pelletized material” or “Solid objects”]	been emitted.		
Wetting at the point of release *[This class should only be visible if the answer to question 3 = “*Powdered, granular or pelletized material” or “Solid objects”]	Wetting systems that wet the process at the point of release (focusing on the emission source) to agglomerate and bind the fine particles to prevent dust from being dispersed into the workroom air.	0.1	
Containment - no extraction	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. This class reflects “add on” enclosures and does not include inherently closed systems (like pipelines)		
- Low level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The process is contained with a loose lid or cover, which is not air tight. This includes tapping molten metal through covered launders and placing a loose lid on a ladle This class also includes bags or liners fitted around transfer points from source to receiving vessel. These include Muller seals, Stott head and single bag, and associated clamps and closures.	0.1	
- Medium level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The material transfer is enclosed with the receiving vessel being docked or sealed to the source vessel. Examples include sealing heads, transfer containers and multiple o-rings. Inflatable packing head with continuous liner ensures a seal is maintained during the powder transfer and the continuous plastic liner prevents direct contact with the product. The correct type of tie off must be used.	0.01	

- High level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The substance is contained within a sealed and enclosed system. This class includes metal smelting furnaces or atomisation units. The material transfer is entirely enclosed with high containment valves (e.g. split butterfly valves and direct couplings, which consist of two sections which connect together to allow the opening of the valve). At the end of the material transfer the two halves are separated, forming a seal on both the process equipment and the material container. The system is designed to minimise the surface area which can contact the material or pairs of valves with wash space between them.	0.001	
Local exhaust ventilation (LEV) - Receiving hoods			
> Canopy hoods	A canopy hood placed over a hot process to receive the plume of contaminant-laden air given off. For cold processes with no thermal uplift, canopy hoods are ineffective.	0.5	
> Other receiving hoods	A receiving hood can be applied wherever a process produces a contaminant cloud with a strong and predictable direction (e.g. a grinding wheel). The contaminant cloud is propelled into the hood by process-induced air movement. The face of the hood must be big enough to receive the contaminant cloud and the extraction empties the hood of contaminated air at least as fast as it is filled.	0.2	
- Capturing hoods			
> Movable capturing hoods	Movable LEV systems such as hoods with extendable arms. The design of the system does not prevent work being performed outside the capture zone of the system and worker behaviour can influence the effectiveness of the system.	0.5	

> Fixed capturing hoods	Fixed capturing hoods located in close proximity of and directed at the source of emission. The design is such that the work is performed in the capture zone of the ventilation system and the capture is indicated at the workplace.	0.1	
> On-tool extraction	LEV systems integrated in a process or equipment that cannot be separated from the primary emission source.	0.1	
- Enclosing hoods			
> Fume cupboard	Any form of permanent encapsulation or encasing of the source of which maximally one side is open with a well designed local exhaust ventilation system (e.g. laminar air flow). The design of both the enclosure and the ventilation system is such that the influence of worker behaviour is minimal (e.g. an alarm system prevents the worker from using the fume cupboard in case the system is not working properly).	0.01	
> Horizontal/downward laminar flow booth	In a horizontal laminar flow booth, contaminated air is extracted through holes situated at the rear of the booth which creates a horizontal laminar air flow. The air is filtered prior to being discharged to the atmosphere. The booth contains the source and has maximally one side open. In a downward laminar flow booth, a curtain of descending laminar air flow is created between the ceiling and the rear of the booth where exhaust grills are located in the lower section. The booth contains the source and has maximally one side open.. Spray rooms and laminar down-flow booths (with the size of a room which contains both the source and the worker) are not considered to be a localised control and will be treated together with the dispersion questions at a later stage.	0.1	

> Other enclosing hoods	Any form of permanent encapsulation or encasing of the source of which maximally the front side is open with a proper local exhaust ventilation system.	0.1	
- Other LEV systems	In case the type of local exhaust ventilation system is unknown or not specified, this default LEV category can be selected. Note that this default category results in a low reduction of the estimated personal exposure level. An attempt should be made to more specifically define the type of local exhaust ventilation.	0.5	
Glove bags and glove boxes			
- Glove bags	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way. An adaption piece is necessary between the glove bag and the process equipment. The glove bag must be designed specifically for the task and the quantity of material to be handled. Various other items such as pass-out boxes, inlet filters, and drains are added to meet specific needs. Note: use of glove bags does not negate the need to implement a long term permanent technological solution.		
> Glove bags (non-ventilated)	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way without exhaust ventilation.	0.01	
> Glove bags (ventilated or kept under negative pressure)	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way. The glove bag is maintained with filtration and ventilation at specific flow rates	0.001	

- Glove boxes	Any form of permanent encapsulation or encasing of the source (which are not opened during the given activity) with a well designed local exhaust ventilation system. The design of both the enclosure and the ventilation system is such that the influence of worker behaviour is minimal (e.g. the enclosure cannot be opened before the substance is properly vented).		
> Low specification glove box	A low specification glove box is specified as: • Single chamber, simple access doors or pass box • Not safe change glove • Single HEPA filtered extract air • Not safe change filters • Manual cleaning	0.001	
> Medium specification glove box	A medium specification glove box is specified as: • Two or more chambers if large area bin docking or high dust levels expected. • Safe change or push through filters are required • Solid (stainless steel) construction for durability. • Size is dependent on the task to be carried out • Safe change filters are required • Air should be single or double HEPA filtered and or exhausted directly to the atmosphere after single HEPA filtration. • The equipment should be maintained under negative pressure and the air flow and filter condition continuously monitored. • Emergency air extraction should start up automatically in the event of a leak or a damaged glove. • Interlocked air locks should be used to prevent high dust concentrations in the area of the transfer ports and reduce risk. (escape of the contaminant during transfer of materials into and out of the glove box).	0.0003	

	- Glove changes should be able to be carried out without breaking containment - Waste disposal ports are required. Correct sealing of continuous liners. - Manual cleaning		
> High specification glove box	A high specification glove box is specified as: - Two or more chambers - Safe change filters are required - Stainless steel construction - Size is dependent on the task to be carried out - Safe change filters are required - Air should be single or double HEPA filtered and or exhausted directly to the atmosphere after single HEPA filtration. - The equipment should be maintained under negative pressure and the air flow and filter condition continuously monitored. - Emergency air extraction should start up automatically in the event of a leak or a damaged glove. - Interlocked air locks should be used to prevent the escape of the contaminant during transfer of materials into and out of the glove box. - Glove changes should be able to be carried out without breaking containment - Waste disposal ports are required. - Integrated sampling and contained drum charging - Sealed and high containment transfer ports (contained transfer couplings, rapid transfer ports (RTPs), alpha/beta valves etc.) - Including waste removal and change parts - Wash in place - Alarmed	0.0001	
Vapour recovery systems	Reduction of vapour emission during storage, loading and off-loading of gasoline or other liquids, and during re-fuelling of a vehicle, by the combination of a vapour collection system and a vapour control unit. Vapour collection is a passive process where the volume of liquid transferred is equal to the volume	0.2	

of vapour transported back to the tank.
The system only works properly when
no other escape openings are present.

Guidance text:

Select the general type of localized controls present for this emission source.
Depending on your selection you may be required to further define the localized controls.
Spray rooms and laminar down-flow booths (with the size of a room which contains both the source and the worker) are not considered to be a localized control and will be treated together with the dispersion questions at a later stage.

Question 130.5:

Are there any secondary control measures in close proximity of the far field emission source intended to minimize emissions from the source in addition to the primary control measure indicated in the previous question? *[Warning text: "the control measure should cover the whole activity"].*

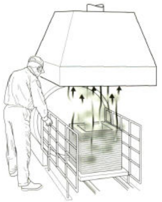
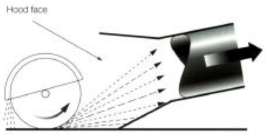
Answer:

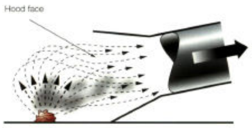
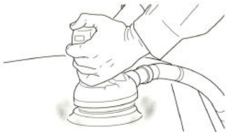
Dropdown list with following possibilities:

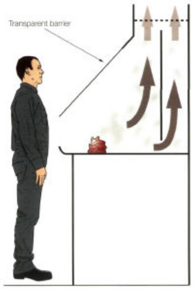
- No secondary localized controls
- Suppression techniques *[This class should only be visible if the answer to question 3 = "*Powdered, granular or pelletized material" or "Solid objects"] -> *go to separate dropdown list for suppression techniques below*
    - Knockdown suppression
    - Wetting at the point of release
- Containment – no extraction *[If this class is selected the answer to the containment question in the activity emission potential should be overruled and set to 'open process']*
    - Low level containment
    - Medium level containment
    - High level containment
- Local exhaust ventilation (LEV) -> *go to separate dropdown list for LEV below*
    - Receiving hoods -> *go to separate dropdown list for receiving hoods below*
        - Canopy hood
        - Other receiving hoods
    - Capturing hoods -> *go to separate dropdown list for capturing hoods below*
        - Movable capturing hood
        - Fixed capturing hood
        - On-tool extraction
    - Enclosing hoods -> *go to separate dropdown list for enclosing hoods below.*
        - Fume cupboard
        - Horizontal/downward laminar flow booth
        - Other enclosing hoods
    - Other LEV systems
- Glove boxes and glove bags *[If this class is selected the answer to the containment question in the activity emission potential should be overruled and set to 'open process']*
        - Glove bags
            - Glove bags (non-ventilated)
            - Glove bags (ventilated or kept under negative pressure)
        - Glove boxes
            - Low specification glove box
            - Medium specification glove box
            - High specification glove box / isolator
- Vapour recovery systems

Descriptions and assigned values of each category are given in the table below.

Classification	**Description**	**Assigned typical value**	**Guidance images**
No secondary localized controls	No secondary control measures in close proximity of the source.	1	
Suppression techniques			
Knockdown suppression *[This class should only be visible if the answer to question 3 = “*Powdered, granular or pelletized material” or “Solid objects”]	Post generation suppression of airborne contaminants to reduce dust levels. Knockdown of a contaminant after it has been emitted.	0.7	
Wetting at the point of release *[This class should only be visible if the answer to question 3 = “*Powdered, granular or pelletized material” or “Solid objects”]	Wetting systems that wet the process at the point of release (focusing on the emission source) to agglomerate and bind the fine particles to prevent dust from being dispersed into the workroom air.	0.1	
Containment - no extraction	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. This class reflects “add on” enclosures and does not include inherently closed systems (like pipelines)		
- Low level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The process is contained with a loose lid or cover, which is not air tight. This includes tapping molten metal through covered launders and placing a loose lid on a ladle This class also includes bags or liners fitted around transfer points from source to receiving vessel. These include Muller seals, Stott head and single bag, and associated clamps and closures.	0.1	

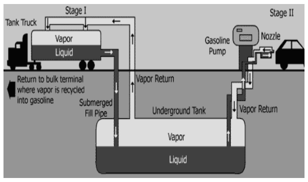
- Medium level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The material transfer is enclosed with the receiving vessel being docked or sealed to the source vessel. Examples include sealing heads, transfer containers and multiple o-rings. Inflatable packing head with continuous liner ensures a seal is maintained during the powder transfer and the continuous plastic liner prevents direct contact with the product. The correct type of tie off must be used.	0.01	
- High level containment	Physical containment or enclosure of the source of emission. The air within the enclosure is not actively ventilated or extracted. The enclosure is not opened during the activity. The substance is contained within a sealed and enclosed system. This class includes metal smelting furnaces or atomisation units. The material transfer is entirely enclosed with high containment valves (e.g. split butterfly valves and direct couplings, which consist of two sections which connect together to allow the opening of the valve). At the end of the material transfer the two halves are separated, forming a seal on both the process equipment and the material container. The system is designed to minimise the surface area which can contact the material or pairs of valves with wash space between them.	0.001	
Local exhaust ventilation (LEV) - Receiving hoods			
> Canopy hoods	A canopy hood placed over a hot process to receive the plume of contaminant-laden air given off. For cold processes with no thermal uplift, canopy hoods are ineffective.	0.5	
> Other receiving hoods	A receiving hood can be applied wherever a process produces a contaminant cloud with a strong and predictable direction (e.g. a grinding wheel). The contaminant cloud is propelled into the hood by process-	0.2	

	induced air movement. The face of the hood must be big enough to receive the contaminant cloud and the extraction empties the hood of contaminated air at least as fast as it is filled.		
- Capturing hoods			
> Movable capturing hoods	Movable LEV systems such as hoods with extendable arms. The design of the system does not prevent work being performed outside the capture zone of the system and worker behaviour can influence the effectiveness of the system.	0.5	
> Fixed capturing hoods	Fixed capturing hoods located in close proximity of and directed at the source of emission. The design is such that the work is performed in the capture zone of the ventilation system and the capture is indicated at the workplace.	0.1	
> On-tool extraction	LEV systems integrated in a process or equipment that cannot be separated from the primary emission source.	0.1	
- Enclosing hoods			
> Fume cupboard	Any form of permanent encapsulation or encasing of the source of which maximally one side is open with a well designed local exhaust ventilation system (e.g. laminar air flow). The design of both the enclosure and the ventilation system is such that the influence of worker behaviour is minimal (e.g. an alarm system prevents the worker from using the fume cupboard in case the system is not working properly).	0.01	
> Horizontal/downward laminar flow booth	In a horizontal laminar flow booth, contaminated air is extracted through holes situated at the rear of the booth which creates a horizontal laminar air flow. The air is filtered prior to being discharged to the atmosphere. The booth contains the source and has maximally one side open. In a downward laminar flow booth, a curtain of descending laminar air flow is created between the ceiling and the rear of the booth where exhaust grills are located in the lower section. The booth	0.1	

	contains the source and has maximally one side open.. Spray rooms and laminar down-flow booths (with the size of a room which contains both the source and the worker) are not considered to be a localised control and will be treated together with the dispersion questions at a later stage.		
> Other enclosing hoods	Any form of permanent encapsulation or encasing of the source of which maximally the front side is open with a proper local exhaust ventilation system.	0.1	
- Other LEV systems	In case the type of local exhaust ventilation system is unknown or not specified, this default LEV category can be selected. Note that this default category results in a low reduction of the estimated personal exposure level. An attempt should be made to more specifically define the type of local exhaust ventilation.	0.5	
Glove bags and glove boxes			
- Glove bags	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way. An adaption piece is necessary between the glove bag and the process equipment. The glove bag must be designed specifically for the task and the quantity of material to be handled. Various other items such as pass-out boxes, inlet filters, and drains are added to meet specific needs. Note: use of glove bags does not negate the need to implement a long term permanent technological solution.		

> Glove bags (non-ventilated)	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way without exhaust ventilation.	0.01	
> Glove bags (ventilated or kept under negative pressure)	Large plastic bags, available in different design and sizes are fitted with gloves which allow products to be handled in a contained way. The glove bag is maintained with filtration and ventilation at specific flow rates	0.001	
- Glove boxes	Any form of permanent encapsulation or encasing of the source (which are not opened during the given activity) with a well designed local exhaust ventilation system. The design of both the enclosure and the ventilation system is such that the influence of worker behaviour is minimal (e.g. the enclosure cannot be opened before the substance is properly vented).		
> Low specification glove box	A low specification glove box is specified as: • Single chamber, simple access doors or pass box • Not safe change glove • Single HEPA filtered extract air • Not safe change filters • Manual cleaning	0.001	
> Medium specification glove box	A medium specification glove box is specified as: • Two or more chambers if large area bin docking or high dust levels expected • Safe change or push through filters are required • Solid (stainless steel) construction for durability. • Size is dependent on the task to be carried out • Safe change filters are required • Air should be single or double HEPA filtered and or exhausted directly to the atmosphere after single HEPA filtration. • The equipment should be maintained under negative pressure and the air flow and filter condition continuously monitored.	0.0003	

	• Emergency air extraction should start up automatically in the event of a leak or a damaged glove. • Interlocked air locks should be used to prevent high dust concentrations in the area of the transfer ports and reduce risk. (escape of the contaminant during transfer of materials into and out of the glove box). • Glove changes should be able to be carried out without breaking containment • Waste disposal ports are required. Correct sealing of continuous liners. • Manual cleaning	
> High specification glove box	A high specification glove box is specified as: • Two or more chambers • Safe change filters are required • Stainless steel construction • Size is dependent on the task to be carried out • Safe change filters are required • Air should be single or double HEPA filtered and or exhausted directly to the atmosphere after single HEPA filtration. • The equipment should be maintained under negative pressure and the air flow and filter condition continuously monitored. • Emergency air extraction should start up automatically in the event of a leak or a damaged glove. • Interlocked air locks should be used to prevent the escape of the contaminant during transfer of materials into and out of the glove box. • Glove changes should be able to be carried out without breaking containment • Waste disposal ports are required. • Integrated sampling and contained drum charging • Sealed and high containment transfer ports (contained transfer couplings, rapid transfer ports (RTPs), alpha/beta valves etc.) • Including waste removal and change parts • Wash in place	0.0001

	• Alarmed		
Vapour recovery systems	Reduction of vapour emission during storage, loading and off-loading of gasoline or other liquids, and during re-fuelling of a vehicle, by the combination of a vapour collection system and a vapour control unit. Vapour collection is a passive process where the volume of liquid transferred is equal to the volume of vapour transported back to the tank. The system only works properly when no other escape openings are present.	0.2	

Guidance text:

Select the secondary type of localized controls present for this emission source.
Depending on your selection you may be required to further define the localized controls.
The system is not protected against any non-existing combinations of localized controls, so be aware to only select a secondary localized control that can be used in combination with the primary localized control indicated in the previous questions.

4.18 Segregation (FF source)

Question 131:
Is the emission source segregated from the work environment by isolation of the source in a segregated room or work area?
Answer:
Dropdown list with following possibilities:

- Partial segregation without ventilation
- Partial segregation with ventilation and filtration of recirculated air
- Complete segregation without ventilation
- Complete segregation with ventilation and filtration of recirculated air
- No segregation

Descriptions and assigned values of each category are given in the table below:

Classification	**Description**	**Assigned value**
Partial segregation without ventilation	Sources are partially segregated from the work environment by isolating the source in a separate room (e.g. with open doors and/or windows to the adjacent area). This segregated area is generally not entered by the worker during a given activity or working shift. The air within the separate room is not actively ventilated.	0.7
Partial segregation with ventilation and filtration of	Sources are partially segregated from the work environment by isolating the source in a separate room (with open doors and/or windows). This segregated area	0.3

recirculated air	is generally not entered by the worker during a given activity or working shift. The air within the separate area is actively ventilated and the recirculated air is filtered or there is no air recirculation.	
Complete segregation without ventilation	Sources are completely segregated from the work environment by isolating the source in a fully enclosed and separate room (incl. closed doors & windows). This segregated area is generally not entered by the worker during a given activity or working shift. The air within the separate area is not ventilated.	0.3
Complete segregation with ventilation and filtration of recirculated air	Sources are completely segregated from the work environment by isolating the source in a fully enclosed and separate room (incl. closed doors & windows). The air within the separate area is actively ventilated and the recirculated air is filtered or there is no air recirculation. The segregated area is generally not entered by the worker during a given activity or working shift.	0.1
No segregation	The source is not isolated from the work environment.	1

Guidance text:

Specify the segregation for this emission source then click Next.

Segregation of the source is defined as isolation of sources from the work environment in a separate room without direct containment of the source itself. The segregated area is not entered by the worker during a given activity or working shift.

[No further questions]

CHAPTER 5

CONCLUSIONS

5 Conclusions

This report describes the mechanistic model that forms the basis for the Advanced REACH Tool, a web based tool for the estimation of inhalation exposure at the workplace. This mechanistic model is built on a conceptual model (Chapter 2; Tielemans et al., 2008) with nine modifying factors (substance emission potential, activity emission potential, localized controls, segregation, dispersion, personal behaviour, surface contamination, personal enclosure, RPE) that determine the personal exposure level. Each of these modifying factors is described in detail in this report, resulting in a classification and relative scoring for each of the modifying factors, which are underpinned with scientific literature, measured exposure data, and expert judgement. Each chapter was subsequently reviewed by one or more leading, international, independent (not part of the ART consortium) experts from industry, research institutes, and public authorities. The mechanistic model is part of the total ART framework that incorporates both a mechanistic model and an empirical part with information from an exposure database. Both parts are combined in a Bayesian statistical framework in order to produce more precise estimates for specific exposure scenarios.

In the mechanistic model, the emission from the source is determined by the substance emission potential (intrinsic properties of the substance) and the activity emission potential (the activity that is performed). Exposures can occur in different forms and can be distinguished in: gases, vapours, dusts (solid aerosols), fumes, mists (liquid aerosols), and fibres. These exposures can be the result of different product types:

- Solid objects (abrasive techniques) (exposure to dust or fumes)
- Powders and granules (exposure to dust or fumes)
- Fibrous material (exposure to fibres)
- Volatile liquids (vapour pressure > 10 Pa) (exposure to vapours or fumes)
- Non-volatile liquids (vapour pressure < 10 Pa) (exposure to mists or fumes)
- Gases (exposure to gases)
- Hot or molten metal (exposure to fumes)

The type of product that is handled determines in combination with the activity that is performed the emission level from the source. This so called activity emission potential describes the potential of an activity to generate emissions into the work environment. To our knowledge, no systematic classification of activities was available for clustering inhalation exposure situations. We therefore developed a system of activity classes, which share their emission generation mechanism(s), physical state of the product handled and the underlying determinants of emission (type and amount of energy transfer, scale of use, product-to-air interface). This classification of activities formed the basis for scoring the activity emission potential.

This mechanistic model is based on the state-of-the-art knowledge and views in exposure assessment and the relative influence of determinants (modifying factors) on personal exposure levels. It is, however, possible that we did not have access to each and every source of scientific information that was available. Some sources might not be publicly available in the peer reviewed scientific literature. The quantitative effect of some of the modifying factors on personal exposure levels was not extensively documented and expert judgement had to be used to supplement this information.

Although ART is designed to be a generically applicable tool that can be used to assess inhalation exposure to a wide variety of substances used during different activities, there are substance groups and activities, for which we do not (yet) recommend to use ART. There was either no scientific information available to derive a relative scoring for these substances and activities or there were no exposure measurement data available to underpin and/or calibrate the relative exposure estimate for these substances and activities. ART version 1.0 cannot be used to assess exposure to:

- Fibrous material
- Solid objects other than wood, stone and metal (e.g. plastics, glass, etc.)
- Gases
- Low-volatile liquids (vapour pressure ≤ 10 Pa) with a very high viscosity (e.g. paste, syrup, etc.)
- Hot processes (e.g. welding, burning, etc.) resulting in fumes

The mechanistic model produces relative exposure rankings. These semi-quantitative rankings will be compared with exposure measurements collected from multiple occupational settings to derive a quantitative algorithm.

5.1 References

Tielemans E, Schneider T, Goede H, Tischer M, van Hemmen JJ, Warren N, Van Tongeren M, Cherrie J, (2008a) Conceptual model for inhalation exposure: defining modifying factors. Ann Occup Hyg 2008; 52: 577-586.

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Signature

Zeist, 9 July 2010

TNO, Quality of Life

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