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Dynamic Olfactometry and Potential Sample Toxicity. Guidelines for a Safe Occupational Health Approach.

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The study reported in this paper examined occupational exposure to potential toxic compounds (PTC) for employees working in dynamic olfactometry, following EN 13725:2003 standard procedures. Potential exposure pathways is limited to inhalation of chemicals in air, through the olfactometer, and for this study it was assumed that no chemical transformations or abatements are induced during the dilution steps or by the different sample lines components. Since the possibility of the dilution apparatus malfunctioning cannot be detected in real time, the exposure scenario assessment was based on an upper bound estimate of exposure, using published values of PTC present in emissions of different activities.
The non-carcinogenic toxicity assessment was based on short term, acute toxicity effects, while for carcinogenic effects, EPA slope factors were used. The dose was based on individual PTC maximum concentration observed multiplied by the forced inspiratory nasal volumes and corrected by the average number of sample presentations.
Different risk scenarios have been calculated for different sample type, both for carcinogenic and non-carcinogenic PTC. Since samples are presented to assessors in an ascending concentration series, i.e. with a lower and lower dilution factor, assessors' exposure is limited to acceptable levels by defining a minimum dilution value, based on specific sample type potential risk, as a guideline for the olfactometric laboratory standard procedures.

1. Introduction

Public concern about environmental odours is increasing more and more and some people who experience odours from industrial activities complaints about health. During public meetings, participants claim that odours made them ill and, even if local specific studies indicate that people suffer from annoyance rather that illness, from the standpoint of the citizen may seem not to differ greatly. From the standpoint of public health, however, even if annoyance and illness do differ greatly, these complaints must be taken in account and local regulation are appearing in order to prevent complaints from residents in the vicinity of important odour sources. As an example, the Regional Guidelines on Odour Emissions in Lombardia have been recently published. Here guidelines that describe impact criteria are proposed and every new facility will have to produce an odour impact assessment study to demonstrate that odour emissions will comply with the impact criteria defined in the guidelines. Existing facilities will have, as well, to define odour impacts, in a 3 km radius, by dispersion modelling of specific odour emissions surveys.

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European Union (EC, 2003) stated that determination of odour concentration can be made, at least until now, only by dynamic olfactometry and EN13725 (2003) procedures were published in order to standardize the methodology within the Member States.
For these reasons an increased number of emission samples, collected in different facilities, from livestock, to wastewater, composting and landfills, to a number of different industrial activities is expected for the olfactometric laboratories. As the number of samples increases more and more, there is an increased concern about assessors' health safety during olfactometry and guidelines for safe working procedures are needed. A revision of the EN 13725 (2003) standard procedures is under way with the CEN/TC 264 and, among the points that will be revised, one will be about health issues. The French standardization body specifically assert that safety procedures "must be increased being the panelist exposition a potential problem and toxicological aspects must be considered on European level or National if more restrictive.
In dynamic olfactometry, diluted odorous air is presented to a panel of assessors through a sniffing port, in order to define odour concentration. No sample filtration is allowed, as this could influence results, and assessors are exposed to the untreated emission sample and to all its PTC. The assessment of occupational risk due to exposure to mixtures of substances is a complex problem but of great importance and relevance. In Italy, to address this problem, recently INAIL, through its Technical Advisory Risk Assessment and Prevention (CONTARP), presented a revision of the "state of the art risk assessment of exposure to mixtures of substances and health effects of workers' (CONTARP, 2009) in which essentially the EPA, ATSDR (Agency for Toxic Substances and Disease Registry) and ACGIH (American Conference of Governmental Industrial Hygienists) approach is described both for non-carcinogenic toxic substances and for carcinogens risk assessment.
Objective of this work is the definition of a conceptual model, for olfactometric laboratories, to define human health risk assessment for workers following EN13725 (2003) standard procedures. The approach used for the evaluation of the occupational hazard in dynamic olfactometry in this work follows the above mentioned approach using the methodologies described by EPA and ATSDR.
The study reported in this paper examined occupational exposure to potential toxic compounds (PTC) for employees working in dynamic olfactometry. By using a risk assessment approach, carcinogenic and non-carcinogenic health effects for different sample types have been evaluated and risk characterization has been evaluated to define safety procedures (Siemiatycki et al., 2004) for workers.

2. Methods

In the conceptual model defined, the primary source of exposure for workers is the sample itself, with its PTC, and air used to dilute samples. The exposure pathways are limited to inhalation as samples for olfactometry are limited to gaseous state.
Workers exposed are the assessors and the panel leader as samples are contained in closed bags, and no operations need to be performed, prior analysis, by other personnel that might come into contact with samples. The panel leader is exposed to potential toxic compounds at a lower level then the assessors since he works remote from the sniffing ports, where contaminated sample is released (after the appropriate dilution) from the olfactometer to the assessors. In the olfactometry conceptual model, potential exposure pathways is therefore limited to assessor's inhalation of chemicals in air, through the olfactometer, and for this study it was assumed that no chemical transformations or abatements are induced during the dilution steps or by the different sample lines components.
Since the possibility of the dilution apparatus malfunctioning cannot be detected in real time, the exposure scenario assessment was based on an upper bound approach, using the maximum estimate of exposure (Reasonable Maximum Exposure, RME), using single point estimates of PTC present in different kind of samples. Each input value has been derived either after an intensive literature search of PTC present in emissions of different activities, or by direct chemical analysis when data was not available.

2.1 Sample categories

Following the identification phase of described PTC, samples have been grouped into homogeneous categories (Table 1), necessary for the great variability in quality and quantity of compounds present in different samples.

Table 1: Sample categories

Sample type	Category
Landfill (presence of landfill gas)	1
Anaerobic digestion of organic material	
Waste water treatment plants (WWTP)	2
Composting	3
MSW treatment	
MSW sorting / pre-treatments	
Foundries	4
General combustion processes	
Livestock Farming	5
Animal Waste Treatment	6
Refinery / Petrochemical / Petroleum and gas storage	7
Ambient Air	8

Objective of the categorization is to define standard safety procedures for homogeneous samples.
The second stage consists of the toxicological assessment of selected substances both for non-carcinogenic toxic substances and carcinogens.

2.2 Non-carcinogenic health effects

The non-carcinogenic toxicity assessment was based on short term, acute toxicity effects, and the Threshold Limit Value - Short Term Exposure Limit (TLV-STEL) was chosen, when available, as reference. Alternatively, when the STEL value was not available, the Threshold Limit Value – Time Weighted Average (TLV-TWA) or the Immediately Dangerous to Life or Health, IDLH values were used (IDLH was used divided by a factor of 10). For each sample category it is considered the maximum concentration (C) of the individual PTC present (based on literature data), its toxicity index (T) expressed as the reciprocal of the reference safety concentration selected (STEL, TWA or IDLH/10) and the associated *Risk* is calculated as follows:

$$Risk = C * T = \sum_{i=1}^{n} C_i * \frac{1}{STEL, TWA\ or\ IDLH_i} \quad (1)$$

In this way, when Risk value is less then 1 it means that is lower than the reference parameter used, and therefore exposure to the specific substance (category) can be considered non-hazardous. When the risk calculated is greater than 1, the exposure to the specific substance (or category) is no longer acceptable and specific safety procedures should be adopted.

2.3 Carcinogenic health effects

For carcinogenic health effects, excess lifetime cancer risk, R, is calculated using EPA slope factors (Woodall and Smith, 2008) values, considering a “non threshold” toxicity and assuming a linear dose-response relationship, as follows:

$$R = CDI * SF \quad (2)$$

Dose is calculated as the chronic daily intake (CDI) for the toxicant:

$$CDI = C * IR * EF * ED / (BW * LT) \quad (3)$$

Where C is the individual carcinogen concentration adjusted with the factors in Table 2:

Table 2: Parameters for carcinogens in samples

Parameter	Value
BW - Body Weight	70 kg
LT - Lifetime	70 y
EF - Exposure Frequency **	21600 s/y
IR - Inhalation Rate = Inspiration Capacity (IC = 3.8 L + TV = 7 mL/kg) * n. presentations (= 5) * n. cycles (= 3) * n. samples/day (=16)	912 L/d
ED - Exposure Duration	10 y

** EF parameter is based on a one year overview, 73 assessors, 13736 individual determinations

Inspiration volume, used to define inhalation rate, assume a forced inspiratory act from normal inspiration and expiration respiratory cycles, and is referred in respiratory physiology as Inspiration Capacity. Respiratory volumes are illustrated in Figure 1 (Vihsadas, 2007).

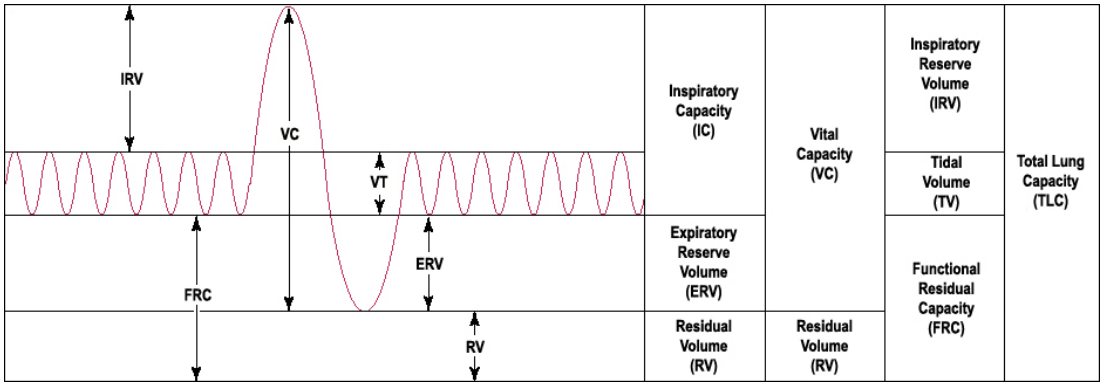

Figure 1. Terms used in respiratory physiology. Inspiratory capacity (IC) has been used in the model defined for this work.

3. Results

Different risk scenarios have been calculated for different sample category, both for carcinogenic and non-carcinogenic PTC and are reported in Table 3.

4. Discussion

In this paper occupational exposure to potential toxic compounds for employees working in dynamic olfactometry, following EN 13725 (2003) standard procedures, has been characterized using a risk assessment approach. The conceptual model defined was conservative and was based on an upper bound exposure scenario, using Reasonable Maximum Exposure to toxicants, with exposure duration of 10 years, considering assessors that perform higher than average but still within a realistic range of exposure.

Results obtained show that during dynamic olfactometry, with the conceptual model defined, exposure to potential toxic compounds gives a potential health risk for assessors. The calculated risk is different for different sample category and is present both for non-carcinogenic, acute health effects and, to a much lower extent, for excess, lifetime, cancer risk.

Table 3: Risk associated with non-carcinogen and carcinogen sample categories in dynamic olfactometry

Sample Type	Category	Risk	
		Non-Carcinogenic Health Effects	Excess Lifetime Cancer Risk
Landfill (presence of landfill gas)	1	2026	$4.7 \cdot 10^{-7}$
Anaerobic digestion of organic material			
WWTP	2	110	$2.5 \cdot 10^{-7}$
Composting	3	141	$2.5 \cdot 10^{-12}$
MSW treatment			
MSW sorting / pre-treatments			
Foundries	4	286	$2.5 \cdot 10^{-6}$
General combustion processes			
livestock farming	5	2842	-
animal waste treatment	6	2205	-
refinery / petrochemical / petroleum and gas storage	7	1	$3.8 \cdot 10^{-7}$
ambient air	8	-	-

Dynamic olfactometry, following European Standard, allows both the “ascending concentration series” (either as a Forced-Choice or a Yes/No) presentation method and the Forced-Choice Probability Method. Based on the results obtained, a safe occupational health approach can be defined taking advantage of the particular exposure in olfactometry, for the “ascending concentration series” methods. Since samples are presented to assessors in an ascending concentration series, i.e. with a lower and lower dilution factor, assessors' exposure can be limited to acceptable levels by defining a minimum starting dilution value, based on specific sample type potential risk, and an absolute minimum dilution value based on odorants’ concentration and toxicants properties. Safety tables for different sample categories can be prepared and used as a guideline for the olfactometric laboratory standard procedures.

Table 4: Critical toxicants in landfill or anaerobic digestion samples, with possible presence of LFG.

Critical Compounds	Non-Carcinogenic Risk	Excess Cancer Risk	Maximum Concentration mg/m3	STEL mg/m3	Olfactory Threshold mg/m3
Acetic acid (Yasuhara et al., 1997)	1251		46300	37	2.25
Methyl mercaptane (McKendry, 2002)	430		430	1	0.0013
Benzene (Yasuhara et al., 1997)		$4.7 \cdot 10^{-7}$	5.03		

As an example, for the first category, samples coming from Landfills or from Anaerobic digestion of organic material, with possible presence of landfill gas (LFG), a minimum starting dilution of 1:2000

must be used in order to protect from potential non-carcinogenic health effects of LFG. Dilution can be progressively reduced, in case of lack of perception of odorous, up to a dilution ratio of 1:100.
Several toxicants (Table 4) are potentially present at levels that will pose a non-carcinogenic health risk at lower dilution but their olfactory threshold will be 4-5 orders of magnitude lower and presence will be detected by the assessors before they will reach harmful concentrations. Several toxicants are present in LFG with non-carcinogenic risk equal to 100, with much higher olfactory threshold, so lower dilutions could be unsafe unless there are evidences that the sample is not pure LFG.
In this case, a minimum dilution of 100 will also give an extra protection from excess cancer risk due to benzene. Not important for this sample category, but necessary for other (foundries, for example).

5. Conclusions

Results obtained with the conceptual model presented in this work, show that employees working in dynamic olfactometry are exposed to a possible health hazard for most of sample categories considered. Risk was found for non-carcinogenic health effects, while an excess lifetime cancer risk has never been observed above accepted exposure levels. Health risks derive from a limited number, of potential toxic compounds that have been described in emissions, assuming that emission gases could be deeply inhaled by assessors. For this reason is important to define minimum dilution values, based on specific sample type potential risk, as a guideline for the olfactometric laboratory standard procedures.

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