

# Occupational Safety for Panellists Involved in Dynamic Olfactometry: a Comparison of Available Risk Assessment Models

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Dynamic olfactometry is nowadays the most diffused technique to quantify odour emitted from industrial plants. The methodology, standardized by EN 13725:2003, involves human assessors, who are potentially exposed to hazardous pollutant present in odorous samples. A standardized method to evaluate the exposure risk for panellist during olfactometric analysis is not yet available. However, two different models to evaluate the occupation risk for panellists have been proposed within the scientific literature. Therefore, this paper reviews the available models and discusses their application to a real sample to estimate the occupation exposure risk for workers involved in olfactometric analyses. After a brief models' description, these are both applied to a real odour sample, highlighting the differences between them and the most critical aspects of applying the suggested procedures for the toxicological assessment of the exposure risk for panellists. This discussion highlights that the absence of a unique standardised assessment method and uniform reference concentrations can lead to significant differences in toxicological evaluations. In addition, the presence of compounds for which no toxicity threshold is available can cause an underestimation of the minimum dilution value to be adopted to protect the health of panellists.

## 1. Introduction

In the last years, odour emitted from different types of industrial facilities has become a pollutant to be monitored (Capelli et al., 2008; Rappert et al., 2005). Indeed, due to the common belief that odour may be related to toxicological health effects, this pollutant is causing an increasing number of complaints from citizens (Hayes et al., 2014). Consequently, the control agencies increasingly require industrial plants to conduct frequent olfactometric monitoring to assess their odour impact (Invernizzi et al., 2016). Nowadays, the most diffuse technique to quantify odour is dynamic olfactometry. This technique is standardised by EN 13725:2003 and leverages the human nose as a sensor able to be stimulated by an odorant (Hangartner et al., 2008; Sironi et al., 2005). As a result, dynamic olfactometry involves directly human examiners, called panellists, to determine odour concentration: the odour concentration is defined as the number of dilutions required for the sample to reach the odour threshold level. Indeed, during the olfactometric analysis, the odorous sample is presented to the panellists at increasing concentrations by olfactometer, the specific equipment that dilutes odour samples according to defined ratios with reference air (Bax et al., 2020). Therefore, during olfactometric measurements, panellists are exposed, at increasing concentration, to the diluted emission' sample, which may contain potentially hazardous pollutants: by this, they are exposed to an unknown occupational risk. The evaluation of toxicological risk appears fundamental to conduct odour measurement in safety condition and guarantee the protection of panellists' health. As the examiners are exposed to increasing concentrations of odorous emissions, the definition of a minimum dilution value, not to be overtaken during analyses, arises as an essential tool to ensure their safety. The importance of this topic was already emphasized in EN 13725:2003. However, occupational safety has become so crucial that it has required further investigation in the current revision of the standard. Indeed, EN 13725:2003 does not provide any detailed discussion. The standard prescribes only to inform the employees involved of the potential

exposure risk correlated with olfactometric analysis and it requires to minimise it (Section 8.6 of EN 13725:2003). For these reasons, the EN 13725 revision should introduce guidance on risk assessment for panel members, prescribing the use of current occupational exposure limits. However, this approach may still be too generic. A method for conducting the exposure risk assessment for panellists has been described in two scientific papers, which have proposed guidelines to determine a minimum dilution level to be applied to odorous samples to protect the health of examiners involved (Davoli et al., 2012, Davoli et al., 2016). Therefore, the proposed models differ in two main aspects: the source of the sample concentration data and the toxicological parameters used. The aim of this work is the discussion and comparison of these two different approaches applied to the toxicological evaluation of a real sample, in order to investigate them and eventually evidence the critical points of the proposed risk assessments.

## 2. State of the art

During their working activity, examiners are exposed to gaseous mixtures collected directly at the odour source, following the sampling requirement of EN 13725:2003. Therefore, the considered odorous samples are not diluted in ambient air, due to atmospheric dispersion, but directly by olfactometer: as mentioned, this instrument dilutes the sample and send it to the sniffers, at increasing concentration, until the assessor distinguish an odour sensation. As a result, panellists can be potentially exposed to a relevant concentration of hazardous pollutants. To conduct a toxicological evaluation for panellists and assess the minimum dilution values useful to guarantee their safety, a preliminary consideration about their exposition should be made.

Firstly, it is necessary to define the type of exposure: due to their activity, panellists have to be considered workers and, as such, their exposure risk has to be estimated by assessing the reference concentrations for this category. Despite this assumption, the particular exposure of panellists during olfactometric analyses must be considered: according to EN 13725:2003, panellists usually work in sessions of 1 or 2 hours to avoid nose fatigue. In addition, each presentation of the odorous diluted sample lasts for a maximum of 15 seconds. For this reason, a panellist involved in dynamic olfactometry will never be exposed for the same length of time as a general worker (8h/day, 40h/week). However, it is still essential to assess the concentration levels to which panellists are exposed during dynamic olfactometry.

To evaluate the exposure risk for panellists, in the scientific literature two approaches were described, using different reference databases to estimate the non-carcinogenic and carcinogenic risk for panellists activity.

In Davoli et al. (2012) (defined in this paper as Approach A), the toxicological evaluation was conducted using emission data available in the scientific literature for different industrial categories. In particular, the maximum concentration of pollutants observed in literature was used to establish the minimum dilution level to be adopted for the odorous samples collected in the different industrial categories considered. In this evaluation, the exposure pathway considered is the inhalation and the study assumes that no chemical reactions or losses occurred during the analysis and samples transportation. To estimate the non-carcinogenic effects correlated to the pollutants exposition, the maximum concentration of substances  $i$ , ( $C_{MAX,i}$ ), observed in the available literature, was considered. As reference concentration ( $C_{REF,i}$ ), Threshold Limit Value - Short Term Exposure Limit (TLV-STEL) was considered. If this value is not defined, either the TLV-TWA (Threshold Limit Value - Time Weighted Average) or the IDLH (Immediately Dangerous to Life or Health) were adopted. IDLH was used divided by a factor of 10. Non-carcinogenic risk ( $R_{NC}$ ) was calculated as:

$$R_{NC} = \sum_{i=1}^n \frac{C_{MAX,i}}{C_{REF,i}} \quad (1)$$

For carcinogenic effects, the excess lifetime cancer risk ( $R_C$ ) for every substance was calculated using EPA Slope Factors and considering that there is no toxicity threshold for these substances. The  $R_C$  was calculated using Eq(2), assuming a linear dose-response relationship:

$$R_{C,i} = CDI_i \cdot SF_i \quad (2)$$

where  $SF_i$  is EPA Slope Factor, expressed  $(\text{mg}/\text{kg}\cdot\text{day})^{-1}$ , and  $CDI_i$  is Chronic Daily Intake for each considered compound, calculated according to panellists characteristics and exposure time as:

$$CDI_i = \frac{C_{MAX,i} \cdot IR \cdot EF \cdot ED}{BW \cdot LT} \quad (3)$$

To calculate  $CDI_i$ , the maximum pollutant concentration observed ( $C_{MAX,i}$ ) is adjusted for panellists exposition, by using panellist body-weight ( $BW$ ), lifetime ( $LT$ ), the exposure frequency ( $EF$ ), the inhalation rate ( $IR$ ) and the exposure duration ( $ED$ ). The global carcinogenic risk ( $R_C$ ) for a category sample is evaluated summing the single carcinogenic contribute ( $R_{C,i}$ ) of different pollutants observed for the class. If  $R_{NC}$  or  $R_C$  are higher than acceptability criteria, reported in Table 1, a minimum dilution value must be set to protect panellists health.

Table 1: Risk acceptability criteria

Risk type	Acceptance parameters
Non-carcinogenic (NC)	$R_{NC} < 1$
Carcinogenic (C)	$R_C < 10^{-6}$ for single substance
	$R_C < 10^{-5}$ for gaseous mixture

The cited paper shows that panellists can be exposed to a potential non-carcinogenic risk during olfactometric analysis ( $R_{NC} > 1$ ), but excess lifetime cancer risk has never been observed beyond accepted exposure levels ( $R_C < 10^{-5}$ ). Therefore, for specific samples categories, a minimum dilution value is proposed to protect examiners from potential non-carcinogenic health effects. For example, for landfills samples, the minimum dilution value to be not accessed, according to this elaboration and literature data available, is 2000.

A different approach is proposed in Davoli et al. (2016). In this study (defined in this paper as Approach B), the model developed by ARPA Piemonte (the Regional Environmental Agency of Piedmont) was applied to establish the exposure risk correlated to samples collected at an Italian municipal solid waste (MSW) incinerator. In this paper, the toxicological evaluation was conducted using the Risk Assessment Information System (RAIS) software. This is a freeware software useful to calculate the non-carcinogenic and carcinogenic risks according to exposure parameters, such as the exposition frequency (EF), duration (ED) and time (ET). These values were assessed for two different olfactometric laboratories: specifically, a private laboratory and an institutional laboratory (the olfactometric laboratory of ARPA Piemonte), characterized by a dissimilar frequency of analysis and so a different number of samples analysed during the year. The exposure risk correlated to MSW incinerator was evaluated using the maximum authorised concentrations ( $C_{AIRi}$ ) at stack emission for chemicals of potential concern (COPs). So, the evaluation was conducted by considering the specific pollutants reported in the plant permit, excluding particulate matter and including metals. The carcinogenic risk and non-carcinogenic risk were calculated by the software for all the pollutants selected, using indoor workers equations inputs for air pollution. The inhalation non-carcinogenic risk for a single pollutant was evaluated as follows:

$$HQ_i = \frac{CDI_{iNC}}{RfC_i} \quad (4)$$

where  $RfC_i$  is the inhalation pollutant reference concentration and  $CDI_{iNC}$  is the inhalation exposure calculated by software using Eq(5). AT is averaging time by the software equal to 365 days/years for indoor workers:

$$CDI_{iNC} = \frac{C_{AIRi} \cdot EF \cdot ED \cdot ET}{AT \cdot ED} \quad (5)$$

The carcinogenic risk for every pollutant was calculated following Eq(6):

$$Inhalation Risk_i = CDI_{iC} \cdot IUR \quad (6)$$

Where  $IUR_i$  is EPA Inhalation unit risk for the pollutant, expressed in  $(mg/m^3)^{-1}$ .  $CDI_{iC}$  is calculated using Eq(7). Here, LT is panellist lifetime:

$$CDI_{iC} = \frac{C_{AIRi} \cdot EF \cdot ED \cdot ET}{AT \cdot LT} \quad (7)$$

The risk values calculated for the individual compounds are then summed to assess the overall risk for the sample. The criteria adopted to evaluate the risk level are similar to Approach A, presented in Table 1. If the acceptability criteria are not satisfied, a minimum dilution value must be set to ensure panel safety. The study evidences that, in the case of samples collected at this particular MSW incinerator, a minimum dilution value should be set at least to 24 for the institutional laboratory and to 73 for the commercial one.

### 3. Discussion

The two models reported in the literature can be very useful because they suggest preliminary guidelines to establish the exposure risk for workers involved in dynamic olfactometry. However, some critical aspects may arise. Firstly, the choice of the toxicological threshold drastically influences the final results, in terms of minimum dilution value. Indeed, nowadays different occupation exposure limit concentrations for chemicals coexist. These values can diverge not only depending on the exposure route and exposure time considered (U.S. Environmental Protection Agency, 1992), but also on the risk assessment and management approach

used (Cattaneo et al., 2018). For these reasons, the absence, in the standard, of an explicit recommendation on the reference concentration to be adopted in the toxicological evaluation can be misleading and lead to an incorrect risk assessment for panellists exposition. The problem becomes evident comparing the reference concentrations adopted by the two models. The reference concentrations differ in definition: Approach A uses thresholds specific for occupational exposure, whereas Approach B uses a threshold for the exposition of the entire population (including sensitive subgroups). Let's consider, for example, the case of a typical odorous molecule, hydrogen sulphide, commonly found in different types of odour emission: in Table 2, the reference concentrations for non-carcinogenic effects related to exposure to H<sub>2</sub>S to be used in the two models are reported.

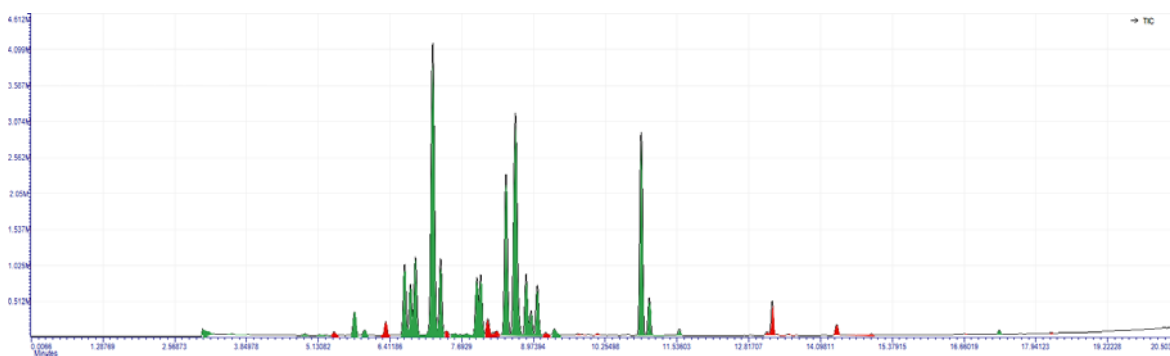
*Table 2: Reference concentration for H<sub>2</sub>S: comparison between two models*

Compound	Approach A (TLV-STEL value available)	Approach B (RfC value)
H <sub>2</sub> S	7 mg/m <sup>3</sup> (ACGIH®, 2020)	0.002 mg/m <sup>3</sup> (RAIS software)

From Table 2, it is possible to observe that, as they are conceptually different thresholds, for the same pollutant the values applied in the two models are significantly different and the selection of one of these two approaches can drastically modify the result of the toxicological evaluation. It is therefore essential, at a regulatory level, to define a uniform source for the reference concentration to obtain comparable values between different laboratories and samples.

A second critical aspect of the two models is correlated to the limited number of reference concentration data available in the suggested databases. Indeed, none of the two models provides information on the treatment, during the toxicological assessment, of compounds for which no threshold is present. This problem, not explicitly addressed in both the approaches, can be critical to evaluate the toxicity of samples characterized by a high number of molecules. Indeed, the absence of a reference value for several compounds present in an odorous sample may lead to an underestimation of the real risk. To discuss this aspect, the two models are applied to a real odorous sample. The case study considered in this elaboration is an oil refinery odour sample, in particular, collected at the outlet of a vapour recovery unit (VRU). In Table 3, the 46 observed pollutants, via GC-MS, are listed: for each detected chemical compound, is reported if either model reports a reference value.

As it is shown in Table 3, for a large number of compounds (between 30 and 75% depending on the approach applied), a specific toxicological threshold for non-carcinogenic effects is not available. Comparing the two models, Approach A appears, in this case, the more complete, because, using Threshold Limit Values (TLVs) databases, only 14 compounds over 46 don't present a reference concentration. However, both the approaches neglect the contribution of these molecules within the assessment of non-carcinogenic risk. Therefore, it is possible to suppose an underestimation of the real risk for panellists correlated with this choice. To address this issue, it is possible to preliminarily evaluate the specific contribution of each compound on the total concentration of compounds observed in the analysed sample: a comparison between the contribution of single pollutants and the availability of exposure limit was conducted using the more complete approach (Approach A).



*Figure 1: Chromatogram of real-case refinery odorous sample - peaks of compounds with an exposure limit are highlighted in green and peaks of compounds without a threshold are displayed in red, in respect of the Approach A.*

Table 3: Application of the two literature approaches to real-case refinery odorous sample for the evaluation of non-carcinogenic effects

Compound	Approach A (Davoli et al., 2012) TLV value available	Approach B (Davoli et al., 2016) RfC value available
Propane	✓	✗
Butane, 2-methyl-	✓	✗
Pentane, 2-methyl-	✓	✗
Pentane, 3-methyl-	✓	✗
1-Pentene, 2-methyl-	✗	✗
n-Hexane	✓	✓
2-Propanol, 2-methyl-	✓	✗
Pentane, 2,4-dimethyl-	✓	✗
1,3-Dioxolane, 2-methyl-	✗	✗
Hexane, 2-methyl-	✓	✗
Benzene	✓	✓
Hexane, 3-methyl-	✓	✗
Butane, 2,2,3,3-tetramethyl-	✓	✗
Heptane	✓	✓
3-Methyl-3-hexene	✗	✗
Hexane, 2,2-dimethyl-	✓	✗
Hexane, 2,5-dimethyl-	✓	✗
Hexane, 2,4-dimethyl-	✓	✗
Pentane, 2,2,3-trimethyl-	✓	✗
Cyclopentane, 1,2,4-trimethyl-	✗	✗
Pentane, 2,3,4-trimethyl-	✓	✗
Pentane, 2,3,3-trimethyl-	✓	✗
Heptane, 3-methyl-	✓	✗
Toluene	✓	✓
Hexane, 2,2,5-trimethyl-	✓	✗
Cyclohexane, 1,3-dimethyl-, cis	✗	✗
Hexane, 3-ethyl-	✓	✗
2-Undecene, 6-methyl-, (Z)-	✗	✗
Heptane, 2,4-dimethyl-	✓	✗
Heptane, 2,6-dimethyl-	✓	✗
Heptane, 2,5-dimethyl-	✓	✗
Octane, 4-methyl-	✓	✗
Ethylbenzene	✓	✓
p-Xylene	✓	✓
Nonane	✓	✓
Styrene	✓	✓
o-Xylene	✓	✓
trans-4-Decene	✗	✗
Decane	✗	✓
cis-3-Decene	✗	✗
Benzene, 1-ethyl-3-methyl-	✗	✓
Dicyclopentadiene	✗	✓
Undecane	✗	✗
Dodecane	✗	✗
Naphthalene	✓	✓
Tridecane	✗	✗

This preliminary evaluation, based on the analysed sample, shows that the total contribution of compounds without an available exposure threshold represents only 3% of the total mass concentration of observed compounds. To show these results, the chromatogram of the sample was reported (Figure 1). Here, the chromatographic peaks were highlighted differently depending on the availability of a threshold limit value: in green, the compounds characterized by a TLV value and in red the compounds without a TLV value.

As visible in Figure 1, it is possible to affirm that the majority of the compounds detected in this sample are characterized by a specific exposure concentration (TLV value) for the non-carcinogenic effect. Therefore, as a first approximation, the compounds for which no threshold value (among STEL, TWA or IDHL limits) is available, could be neglected due to their very slight overall contribution. This consideration is only a preliminary approach to this issue. Indeed, the choice of neglecting the TLV-missing compounds could be adopted only if their concentrations are very low compared to the others. However, this approximation cannot be generally adopted but has to be discussed on a case-by-case basis. Indeed, if the contribution of compounds without a defined toxicological threshold cannot be neglected, further assessment will be necessary on evaluating their potential toxicity, in order to conduct the toxicological evaluation of exposure risk for panellists.

#### 4. Conclusion

The evaluation of panellists exposure risk, during olfactometric analysis, and the definition of a minimum dilution value appears crucial. Although the problem has been known for a long time, a standardized procedure has not yet defined. This work aims to describe the two models available in literature and examine their possible difficulties if they are applied to a real-case odorous sample. The selection of the reference concentration, for the elaboration, is fundamental to obtain reproducible and reliable minimum dilution values among different olfactometric laboratories. In addition, the absence of an exposure limit for many pollutants, actually present in an olfactometric sample, may lead to an underestimation of the potential risk. As a first trial hypothesis, these compounds could be neglected if they are present at very low concentrations. Otherwise, it will be necessary to evaluate a specific method for estimating the hazard associated with the presence of these compounds.

#### References

- ACGIH® (2020). ACGIH® Threshold Limit Values (TLVs®) and Biological Exposure Indices (BEIs®).
- Bax, C., Sironi, S., Capelli, L. (2020). How Can Odors Be Measured? An Overview of Methods and Their Applications. *Atmosphere*, 11 (1), 92. <https://doi.org/10.3390/atmos11010092>
- Capelli, L., Sironi, S., Del Rosso, R., Céntola, P., Il Grande, M. (2008). A comparative and critical evaluation of odour assessment methods on a landfill site. *Atmospheric Environment*, 42 (30), 7050–7058. <https://doi.org/10.1016/j.atmosenv.2008.06.009>
- Cattaneo, A., Spinazzè, A., Cavallo, D. M. (2018). Occupational exposure limit values for chemical risk assessment at European level. *Italian Journal of Occupational and Environmental Hygiene*, 9(October), 93–97.
- Davoli, E., Zuccato, E., Bianchi, G., Il Grande, M., Bonati, S., Rossi, A. N., Porporato, C., Pereno, M., & Soldati, S. (2016). Dynamic olfactometry and sample toxicity. a case study for a MSW incinerator odour assessment project. *Chemical Engineering Transactions*, 54, 13–18. <https://doi.org/10.3303/CET1654003>
- Davoli, E., Zuccato, E., Bianchi, G., Palmiotto, M., Il Grande, M., Bonati, S., Rossi, A. N. (2012). Dynamic Olfactometry and Potential Sample Toxicity. Guidelines for a Safe Occupational Health Approach. *Chemical Engineering Transactions*, 30. <https://doi.org/10.3303/CET1230002>
- Hangartner, M., Hartung, J., Paduch, M. (2008). Voorburg (1989) Improved recommendations on olfactometric measurements. *Environmental Technology*, 10 (2), 231–236. <https://doi.org/10.1080/09593338909384736>
- Hayes, J. E., Stevenson, R. J., Stuetz, R. M. (2014). The impact of malodour on communities: A review of assessment techniques. *Science of the Total Environment*, 500–501, 395–407. <https://doi.org/10.1016/j.scitotenv.2014.09.003>
- Invernizzi, M., Capelli, L., Sironi, S. (2016). Quantification of odour annoyance-nuisance. *Chemical Engineering Transactions*, 54, 205–210. <https://doi.org/10.3303/CET1654035>
- RAIS. RAIS Chemical Risk Calculator. Retrieved January 17, 2021, from [https://rais.ornl.gov/cgi-bin/prg/RISK\\_search?select=chem](https://rais.ornl.gov/cgi-bin/prg/RISK_search?select=chem)
- Rappert, S., Müller, R. (2005). Odor compounds in waste gas emissions from agricultural operations and food industries. *Waste Management*, 25(9), 887–907. <https://doi.org/10.1016/j.wasman.2005.07.008>
- Sironi, S., Capelli, L., Céntola, P., Del Rosso, R., Il Grande, M. (2005). Odour emission factors for assessment and prediction of Italian MSW landfills odour impact. *Atmospheric Environment*, 39 (29), 5387–5394. <https://doi.org/10.1016/j.atmosenv.2005.05.023>
- U.S. Environmental Protection Agency (1992). Guidelines for Exposure Assessment.