ODOUR IMPACT ASSESSMENT METHODS OVERVIEW: THE ODOUR OBSERVATORY AS AN INFORMATIVE TOOL FOR CITIZEN SCIENCE BASED APPROACHES TO ODOUR MANAGEMENT

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ABSTRACT: Odour pollution is nowadays a well-known problem related to different industrial activities and the main cause of citizens' complaints to local authorities. In order to avoid socio-environmental conflicts within the impacted communities, specific programs are needed to manage odour pollution problems. The H2020 project D-NOSES (Distributed Network for Odour Sensing, Empowerment and Sustainability) aims to help citizens co-create local solutions together with industries, regional & local authorities, and odour experts; thereby developing a bottom-up approach for the management of odour pollution problems based on citizen science. The first aim of this article is to introduce the D-NOSES project and its methodology. Aside from that, it presents an overview of the existing odour impact assessment methods currently used to quantify odour pollution. This overview will be made available through the Interntational Odour Observatory, a platform to be developed under the D-NOSES project to help promote odour pollution management and resolve regulation issues. Finally, the different odour measurement methods are compared in terms of their applicability and limitations. This is only the first step for the development of the Odour Observatory, which in the future will also need to include information about odour abatement systems, chemical substances in odour emissions, and odour regulations around the world.

Keywords: odour measurement, olfactometry, odour pollution, odour emissions, ambient air, odour monitoring

1. INTRODUCTION

Odour pollution is nowadays a well-known problem related to different industrial activities and the main cause of citizens' complaints to local authorities (Henshaw et al., 2006). This is particularly true when waste treatment facilities are involved (Lucernoni et al., 2017; Marchand et al., 2013; Sironi et al., 2006). Although odour emissions are generally considered harmless, in some cases they may cause adverse health effects for citizens that go beyond mere inconvenience (Aatamila et al., 2011). In order to avoid socio-environmental conflicts within the impacted communities, specific programs are needed to manage

odour pollution problems.

Combining Citizen Science and participatory strategies, the H2020 project D-NOSES (Distributed Network for Odour Sensing, Empowerment and Sustainability) aims to help citizens to co-create local solutions together with industries, regional & local authorities, and odour experts. Ten pilots are being launched in ten European and non-European countries to validate the methodology. Each pilot will involve citizens to collect data, use varying techniques for validation, and then apply a stakeholder engagement framework to improve the management of odour pollution issues at a local level. The D-NOSES project is based on the idea that using citizen science to monitor odour pollution has a clear advantage, since citizens already have the best sensor available to measure odours, i.e. their own noses. The OdourCollect mobile App (OdourCollect.eu) was specifically created for this project to provide a platform that empowers citizens to gather odour observations and co-create collaborative odour maps in affected communities.

In addition, the International Odour Observatory is under construction to create a one-stop-shop for odour management issues. The observatory will gather odour data, raise awareness, and make environmental information available to all interested stakeholders. One section will be dedicated specigically to informing people about the scientific and regulatory framework in odour pollution.This section will provide useful data regarding, for instance, the chemicals that are associated with odour emissions from different activities, the systems that can be used to reduce odour emissions, and existing odour regulations.

The observatory aims to inform stakeholders at all different levels, including general citizens concerned with odour pollution. One of the main questions regarding odour pollution that often arises from citizens is: “Can odours be measured?”. For this reason, one of the first objectives for the Odour Observatory is to answer this question by explaining that it is possible to measure odours, and provide an overview on the methods that can be used for this purpose as well as for assessing odour impacts in a simplified and accessible manner.

This paper has the aim on one hand to introduce the D-NOSES project and its methodology, and on the other to give an overview of the existing odour impact assessment methods that can be applied to quantify odour pollution, also explaining how this information will be made available through the Odour Observatory so that it can be used to compare different methods and help foster a common approach based on best-practices.

2. THE D-NOSES PROJECT: OVERALL AIMS AND STRATEGY

The overall aim of the D-NOSES project is to develop and validate a methodology for odour pollution management based on a bottom-up approach. This approach focuses on using participatory strategies for citizen involvement, engagement with a broas set of quadruple helix stakeholders, and the co-creation of practical and balanced solutions. To reach this goal, D-NOSES intends to:

- Raise awareness about odour pollution, and address environmental and sanitation related problems, through a multi-level engagement strategy at global, national and local levels, paving the way for increased sustainability and quality of life;
- Provide access to information by creating The International Odour Observatory;
- Collect evidence through 10 local case studies in European and non-European countries to validate the methodologies;
- Provide common scientific guidelines for policymaking;
- Produce a Green Paper and a Strategic Roadmap for Governance in odour pollution to advocate and inform the development of common, bottom-up, efficient and coherent regulations.

According to the above listed points, one of the Work Packages (WPs) of the project is devoted to the description of the current scientific and regulatory frameworks for odour pollution across different regions. This knowledge base will be one of the pillars the International Odour Observatory, the purpose of which will be to provide a single point of reference for all stakeholders who are involved with odour pollution

issues.Indeed, in order to reach the goal of creating common scientific guidelines for policy making, it is extremely important to define the problem by identifying relevant odour sources, up-to-date techniques for odour impact assessment and for odour abatement, as well as the current policies and regulations in European and extra-European countries.

3. THE INTERNATIONAL ODOUR OBSERVATORY

3.1 The Odour Observatory as an informative tool for citizens

Despite being the second largest reason for environmental complaints in Europe (Marchand et al., 2013), information and advice about odour pollution can be hard to find. Especially among citizens, the level of knowledge about fundamental aspects related to odour pollution tends to be scarce. It is not rare to hear questions such as: “What is an odour?” or “Is there a way to measure odours?”. This lack of basic information could severely limit the success of any proposed bottom-up methodology for the management of odour pollution problems. Recognising this limitation, one of the main objectives of the D-NOSES project is the creation of the ”International Odour Observatory”. The observatory will help to promote citizen science in odour management, help gather data about odour pollution problems, and make relevant and actionable environmental information available to all interested stakeholders.

More in detail, the Odour Observatory will have a “Get informed” section (Figure 1) housing information on which regulations apply in different parts of the world, how odours can be measured and all other issues related to odour pollution. This information will be the first step in educating stakholders about odour pollution and provide an entry point into getting involved more actively in the issues.

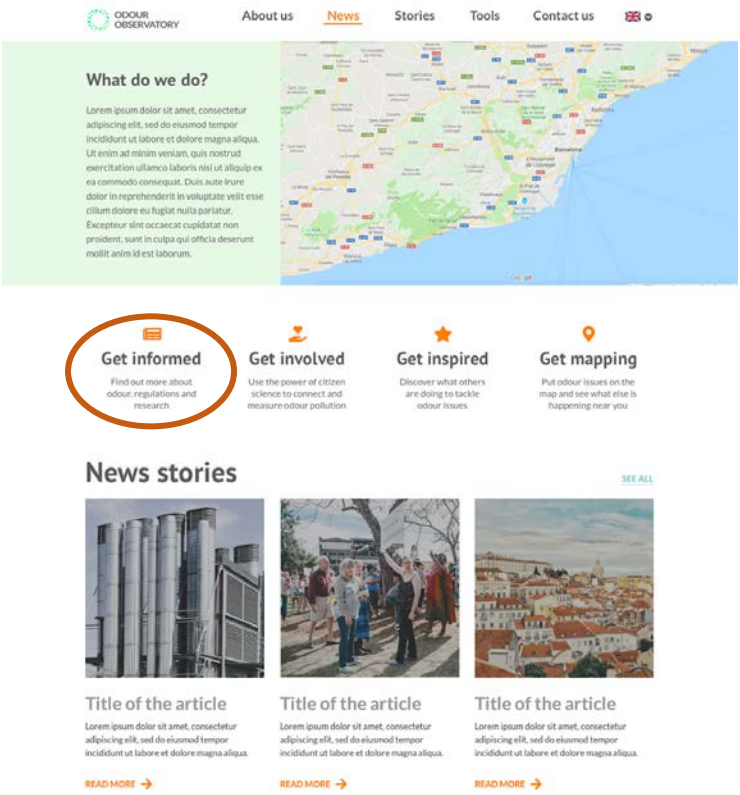

Figure 1. Example of homepage of the Odour Observatory (under construction)

3.2 Structure of the section describing how odours can be measured

One of the main questions that the Odour Observatory will answer is: “How can odours be measured?”. For this purpose, after extensive bibliographic research, a preliminary document has been created that schematizes the existing methods for odour measurement. Each method has been described briefly and in simple language by answering the following questions:

- What is it? (Method description)
- What can it be used for? (Applicability)
- What can it not be used for? (Limitations)

Each entry will be complemented with some examples of relevant applications as well as a list of links to selected reference articles for further detailed information. This way the observatory can serve the needs of both a technical as well as lay audience.

4. OVERVIEW OF ODOUR IMPACT ASSESSMENT METHODS

4.1 General schematization of odour impact assessment methods

As a first step, the existing odour impact assessment methods were identified, and an attempt was made to schematize them depending on the type of method (mathematical methods, instrumental measurements and sensorial measurements) and on where they can be applied (emissions vs. ambient air). The resulting scheme is shown in Figure 2.

In order to provide an overview of the existing odour impact assessment methods, the following paragraphs present a very short description of each method, then the last paragraph provides a comparison of the different methods in terms of applicability and limitations. Currently this overview only focuses on methods for odour measurements, leaving out mathematical methods.

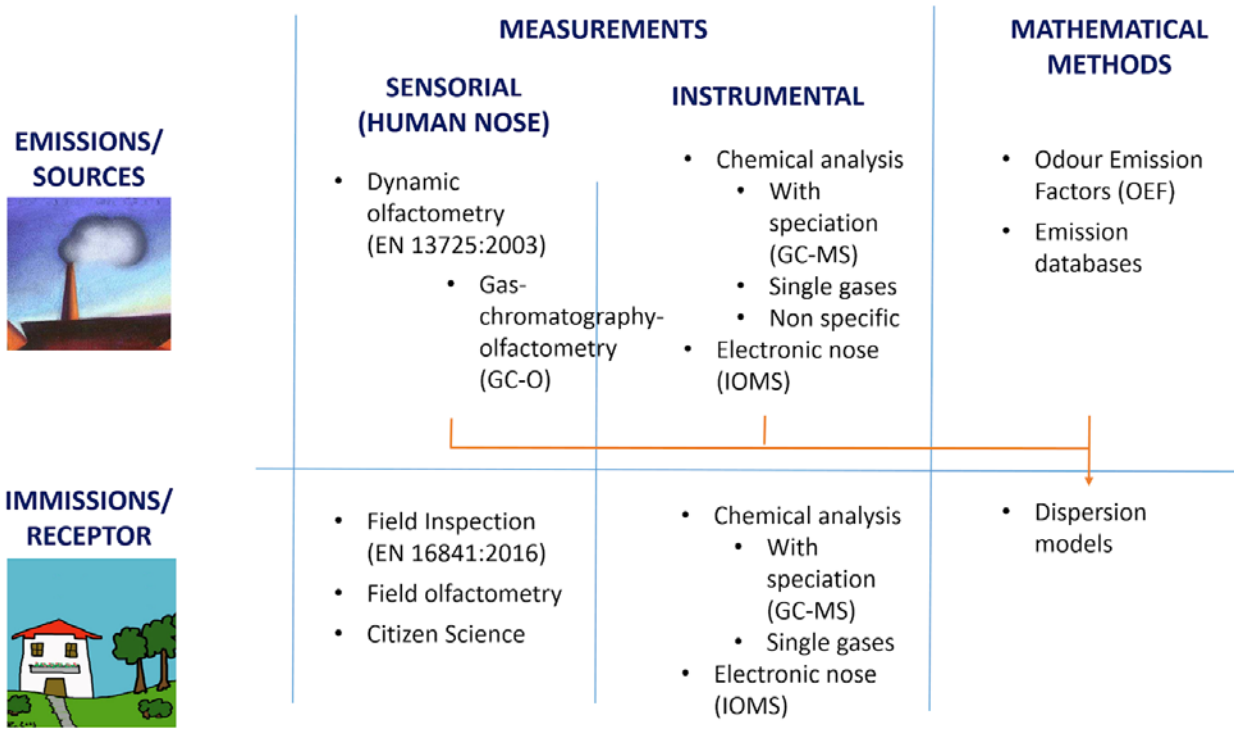

Figure 2. Schematization of odour impact assessment methods

4.2 Dynamic olfactometry

Dynamic olfactometry is a standardized sensorial technique for measuring odour concentrations using the human sense of smell (CEN, 2003). It is related to the sensation caused by a sample directly on a panel of opportunely selected people.

The outcome of this measurement is the odour concentration of the sample, expressed in European odour units per cubic meter (ou_E/m^3). This represents the number of times the sample has been diluted with neutral air to reach its odour detection threshold concentration. Thus, if the sample needs to be diluted 100 times with clean air so that the panel cannot perceive the odour anymore, this means that the sample has a concentration of 100 ou_E/m^3.

Samples of odorous air are collected at the source of the odour in bags. The analysis is carried out by presenting the sample to the panel at increasing concentrations by means of a dilution device called an olfactometer, until the panel members can detect an odour that is different from the reference air.

4.3 Chemical analysis – with speciation

Chemical analysis (with speciation) of odours is an instrumental analysis for the complete identification and quantification of odorous chemical compounds in an odour sample. It is an “instrumental analysis”: the main technique is Gas Chromatography coupled with Mass Spectrometry (GC-MS). GC - MS is a technique that combines the separation capability of gas chromatography (GC) with mass spectrometry (MS), which allows for the identification of the separated compounds.

GC can separate molecules depending on their chemical-physical properties. MS breaks each molecule into ionized fragments, obtaining a mass spectrum. A mass spectrum is a molecule fingerprint, that is characteristic and can be used to uniquely identify a substance.

4.4 Gas-chromatography-Olfactometry (GC-O)

It is a method that combines the information provided by chemical characterization and by odour perception. GC-O utilises a GC-MS system equipped with an olfactory detection port: at the outlet of the GC there is a sniffer mask, where a trained panelist can smell the gas and provide information about the presence of odour in it.

4.5 Chemical analysis – non-specific

In cases where the odour problem is specifically related to hydrocarbon molecules, a non-specific gas analysis can be applied as a preliminary screening tool to assess the total amount of hydrocarbon compounds by means of easily transportable and inexpensive tools, like FID (Flame Ionization Detector) or PID (Photo Ionization Detector).

These tools are based on the pyrolysis of the organic compounds, made possible by the presence of an energy source (hydrogen flame for FID, UV lamp for PID). This produces ions which are detectable by an electric sensor.

4.6 Chemical analysis – single gases

In those rare cases in which the odour pollution problem is due mainly to a single compound, such as NH_3 or H_2S, a reliable quantification of odours (in emissions or in ambient air) can be obtained by assessing the concentration of these single gases.

There are specific technical norms that define the sampling and analysis methods for the measurement of single gases in emissions. When the concentrations are quite high (1-10 ppm) it is possible to use electrochemical sensors, which are easy to use and cheap.

When applying the analysis of single gases to ambient air, the compound to be measured should not

be ubiquitous; its source must be clearly identifiable. When concentrations are low, more complex and expensive tools are needed, like a chemiluminescence analyzer for NH_3 or gold foil instruments for H_2S.

4.7 Instrumental odour monitoring (E-noses)

An electronic nose is a piece of equipment designed to mimic the mammalian olfaction in the detection and characterization of simple or complex odours.

These devices allow the identification of mixtures of organic samples as a whole, providing their olfactory fingerprint, without recognizing the individual odor-generating compounds. In the same way as the human nose doesn't need to identify each single odorant molecule to distinguish the odour of an apple from rotten eggs.

To do this, the instrument must be trained: it must be provided with a database of olfactory fingerprints relating to the odours to which it may be exposed to during the analysis. That database is put together by analyzing air samples with known olfactory qualities at different odour concentration and thus defining the olfactory classes (odour types) to be recognized.

4.8 Field inspection

The main idea behind field inspections is to estimate the degree of annoyance in a determined problematic area by means of the olfactory capacities of a group of people (panel). The panel is specially trained and "calibrated" for this purpose. This method has been recently standardized by a specific European Norm (CEN, 2016a,b).

Two different approaches for field inspection can be applied:

- Grid method (CEN, 2016a): uses direct assessment of ambient air by panel members to characterize odour exposure in a defined assessment area;
- Plume method (CEN, 2016b): determines the extent of the downwind odour plume of a source (there is no direct relation between the presence of recognizable odours and the occurrence of odour annoyance).

4.9 Citizen Science

The Citizen Science approach to monitoring odour harnesses the power of crowds, using one of the most effective odour sensors - the human nose. Communities can record the frequency, intensity and type of odour that they experience and combine many individual observations to build a clear picture of the issue. As more citizens are involved in sharing their findings, or data, the level of subjectivity is reduced. The D-NOSES project will use this technique, and aims to develop and validate a citizen science based bottom-up approach for odour pollution management.

4.10 Comparison of methods

The above-mentioned methods are based on different principles and thus can be used to provide very different type of answers. For this reason, it is difficult to make a comparison of such methods. A limited comparison can be provided by stating the limits of applicability of each method, fixing clearly what they should or should not be used for. This type of information, which will be provided in the Odour Observatory, is summarized schematically in Table 1.

Table 1. Schematization of different odour measurement methods in terms of their applicability and limitations

Measurement method	Applicable to emissions or ambient air	Applicability	Limitations
Dynamic olfactometry	Emissions	• Measure the concentration of odours emitted at the source • Ascertain if regulations are being breached • Provide information that can be used as input data for dispersion modelling in order to evaluate citizens' exposure odours	• Non-continuous monitoring of odour emissions (discontinuous method) • No information about odour quality; it cannot identify odours or distinguish different odours • No information about presence of odours in ambient air (immissions): it only provides information about odour emissions
Chemical analysis – with speciation	Emissions and/ or ambient air	• Obtain information about the chemical composition of odours • Identification and quantification of the chemical compounds that are present in an odour emission or in ambient air can be used for the evaluation of the impact on the environment and human health	• Very difficult and not always effective, especially in the characterization of complex odours • Odours are not additive due to synergistic and masking effects between odorants, thus chemical composition of an odorous sample can not be related to its odour concentration • Less sensitive than human nose for malodorous compounds with low odour threshold
Gas-chromatography-Olfactometry (GC-O)	Emissions	• Gain information about the odour character associated with the different molecules contained in an odour sample, and thus odour quality • High sensitivity: human nose is more sensitive than an instrumental detector; the human nose is sometimes able to detect the presence of odours also where the chromatogram doesn't show any peak	• No information about the odour concentration of the sample. • Because of the separation of the sample in its single components, the olfactory properties of the sample as a whole are not considered. • Cannot provide information about the odour impact, and neither can it be used directly as input for dispersion modelling
Chemical analysis – non-specific	Emissions	• Detection of gas leaks, which are potentially associated with diffuse odour emissions • Very useful in the detection of fugitive emissions from equipment or piping in refineries, or leaks in landfill soils	• No information about the odour properties of the analyzed gas
Chemical analysis – single gases	Emissions and/ or ambient air	• Quantify the concentration of single gases in emissions or ambient air • Estimate the odour concentration in emissions, in those rare cases in which the emitted odour is directly correlated to one specific compound (tracer) • Measure the impact of odour in ambient air, in those rare cases in which the odour is directly correlated to one specific compound (tracer), and the source can be univocally identified	• Useless in the case of complex odorous mixtures, whereby odour concentration is not related to the concentration of one single component; this is the most common case, since environmental odours are mixtures of hundreds of different compounds. • No information about the composition of complex mixtures

Measurement method	Applicable to emissions or ambient air	Applicability	Limitations
Instrumental odour monitoring (E-noses)	Emissions and/ or ambient air	• Continuous and fast results with a limited budget • Continuous measurement of odour concentration at emissions, e.g., for continuous monitoring of odour abatement systems efficiency • Direct determination of the odour impact at receptors and identification of odour provenance	• No information about intensity and pleasantness of the odour • Cannot substitute dynamic olfactometry
Field inspections	Ambient air	• Estimate the degree of annoyance in terms of “odour hours” in a determined problematic area (“grid method”) • Determine the extent of the odour plume from a facility under specific meteorological conditions (“plume method”) • With a suitable training, assessors may provide information about odour quality	• No information about odour concentration
Citizen science	Ambient air	• Involve citizens in the process of odour impact assessment • Estimate the degree of annoyance by directky referring to the effect on citizens	• Risk of biased information • Hardly applicable in conflictual situations (e.g., law suits)

5. CONCLUSIONS AND FUTURE WORK

As stated earlier, the aim of the D-NOSES project is to develop a methodology for odour pollution management based on a bottom-up approach focusing on participatory strategies to involve citizens and engage quadruple helix stakeholders in the co-creation of relevant solutions.

To actively involve citizens in the process, it is important that they start with sufficient knowledge to be able to take part effectively. For this reason, the project emphasizes the accessibility of basic information such as the definition of an odour and the basic principles for odour measurement. This should be achieved by the creation of the “International Odour Observatory”, which will present simple and relevant environmental information through an easily accessible “get informed” section. The observatory will also address more sophisticated and technical audiences by offering more detailed information to those that are interested.

In this frame, this paper describes the first part of the information that will be included in the Odour Observatory, with the purpose of providing an answer to the question “How can odours be measured?”. An overview and a short description of the different existing odour measurement methods is given here, distinguishing them based on the type of method (mathematical methods, instrumental measurements and sensorial measurements) and on where they should be applied (emissions vs. ambient air). Moreover, a schematic comparison of the different methods is given in terms of their applicability and limitations.

This overview of odour measurement methods is only the first part of the information that should be made available through the Odour Observatory. The next questions that will need to be answered for the development of the Odour Observatory concern: i) the available techniques that can be adopted to reduce odour emissions (odour abatement systems), ii) the presence of – potentially hazardous – chemical substances that can be found in odour emissions, and iii) existing regulations and impact criteria regarding odour impacts in European and non-European countries.

All this information is a basis to set the scientific and regulatory framework for odour pollution and thus provide a comprehensive knowledge base, which is a fundamental step in developing a methodology that

aims to involve quadruple helix stakeholders in the entire process of odour pollution management.

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REFERENCES

Aatamila, M., Verkasalo, P. K., Korhonen, M. J., Suominen, A. L., Hirvonen, M. R., Viluksela, M. K., & Nevalainen, A. (2011). Odour annoyance and physical symptoms among residents living near waste treatment centres. Environmental Research, 111(1), 164-170.

CEN, (2003). EN 13725:2003. Air Quality – Determination of Odor Concentration by Dynamic Olfactometry. Brussels, Belgium.

CEN (2016a). EN 16841-2:2016. Ambient air - Determination of odour in ambient air by using field inspection - Part 2: Plume method. Brussels, Belgium.

CEN, (2016b). EN 16841-2:2016. Ambient air - Determination of odour in ambient air by using field inspection - Part 1: Grid method. Brussels, Belgium.

Henshaw, P., Nicell, J., & Sikdar, A. (2006). Parameters for the assessment of odour impacts on communities. Atmospheric Environment, 40, 1016-1029. https://doi.org/10.1016/j.atmosenv.2005.11.014

Lucernoni, F., Capelli, L., & Sironi, S. (2017). Comparison of different approaches for the estimation of odour emissions from landfill surfaces. Waste management, 63, 345-353. https://doi.org/10.1016/j.wasman.2016.09.041

Marchand, M., Aissani, L., Mallard, P., Béline, F., & Réveret, J. P. (2013). Odour and life cycle assessment (LCA) in waste management: a local assessment proposal. Waste and Biomass Valorization, 4(3), 607-617. https://doi.org/10.1007/s12649-012-9173-z

Sironi, S., Capelli, L., Céntola, P., Del Rosso, R., & Il Grande, M. (2006). Odour emission factors for the prediction of odour emissions from plants for the mechanical and biological treatment of MSW. Atmospheric Environment, 40(39), 7632-7643. https://doi.org/10.1016/j.atmosenv.2006.06.052

Sironi, S., Capelli, L., & Del Rosso, R., (2014). Odor Emissions, pp. 1-23. In: Elsevier Reference Module in Chemistry, Molecular Sciences and Chemical Engineering. J. Reedijk (Ed.), Elsevier, Waltham, MA.