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A New Methodology Based on Citizen Science to Improve Environmental Odour Management

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This paper outlines a new methodology to gather valid real time odour observations in the impact area of an odour emitting activity by using citizen science tools and a quadruple helix approach (Cavallini et al., 2016), to involve the public authorities, the odour emitting industries, the Academia and the citizens and co-design local solutions to reduce nuisance. The results of the proposed innovative bottom-up approach can contribute to identify improvements in the daily practice of the industries such us operations that cause peaks of emissions, or the critical times of the day that increase nuisance due to non-favourable meteorological conditions, while improving the relationships with the citizens and the local environmental authorities, as well as increasing transparency. In addition, the cost of traditional odour studies can be reduced since the real time odour observations gathered by the citizens have no associated costs.

1. Introduction

Traditional methods to tackle odour pollution, including measurements of the odour concentration at the source by dynamic olfactometry according to the European Standard EN 13725:2003 and posterior impact modelling, as well as pre-programmed field observations following the recent European Standard EN 16841:2016, fail to provide real time data or odour observations when nuisance arises. In the case of olfactometry, the time lapse between sampling and analysis could cause degradation effects in the sampling bag, diffusion through the bags and/or sorption or chemical reaction between components, making the analysed odour different from what neighbours of the source are exposed to (Van Elst et al., 2016). Although these methodologies nowadays constitute a routine method in environmental odour management to calculate an odour impact, this odour assessment is not always useful for evaluating the day to day operation of an odour emitting industry (Díaz et al., 2016).
In situations with complex odour emitting sources, such as diffuse sources, or several sources with potential interactions between the different types of odours co-existing in the same area, alternative methodologies are used to estimate the overall impact or the extent of the odour plume. An example is the Plume Method, which reflects the actual perceptibility of an odour in the environment and constitutes the base of odour policy in Flanders. In this method, at least two experienced panel members (certified according to EN 13725), traverse independently the plume, while conducting single measurements (observations during one inhalation) at frequent intervals. To reduce the uncertainty caused by modelling and assess the impact of an odour source on the neighbours, telephonic enquiries or questionnaires can be used. These methods can also generate useful interactions and construct a link between affected neighbours, the odour-emitting company and the local administration, in some cases resulting in a much better understanding of the problem and the difficulties to control the emissions (Van Elst et al., 2016).
In some countries, citizen surveys have been used extensively to gather data on odour nuisance. As an example, the guide IPPC H4 on Odour Management from the UK Environment Agency (2011) recommends the recruitment of community members to perform surveys or keep odour diaries to evaluate the level of odour annoyance and start building up a pattern of odour problems over time, which can then be associated with

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other factors such as wind direction and site activities. Similar procedures are also foreseen by the German guideline VDI 3883:2015, and by different regional guidelines in Italy.
A new bottom-up approach is here proposed based on real-time odour observations made by citizens in the odour impact area and a quadruple helix model, involving the odour emitting industries, the public authorities, the Academia and the citizens, to reverse the way in which odour pollution is traditionally managed.

2. Citizen science for monitoring odour pollution

2.1 The emergence of citizen science

In recent years, citizen science projects have rapidly multiplied at a global level, covering a numerous range of topics. Internet and the increased number of smartphones facilitates citizens to become researchers, sensors, or advocates. Budget cuts make citizen science an attractive method to bolster limited, or even declining, governmental resources. Big data supports large-scale data collection and analysis, often augmenting human intelligence with support from computational systems. In addition, there is a growing movement of people across Europe developing inspiring digital solutions to social challenges under the umbrella of Digital Social Innovation (DSI). These digital solutions have developed thanks to the open source and open data movements, low-cost open hardware, crowdsourcing and Internet of Things (IoT), and have enabled borderless collaborations. In other research areas, such as biodiversity studies, data collected by citizens is one of the main sources of valid knowledge for science (Chandler et al., 2017).
In addition, the scale and scope of the current wave of engagement shifts citizen science from the outer margins of scientific activities to the centre and thus calls for attention from policymakers. Indeed, UNESCO (UNESCO, 2013), the European Environment Agency (EEA, 2013), national level policy bodies such as the Scottish Environmental Protection Agency and the UK Environmental Observation Framework (SEPA, 2014), and the European Commission (White Paper on Citizen Science, 2014), have recognised the importance of citizen science for their present activities and future policy directions.

2.2 The App OdourCollect: Citizen science applied to measuring odours in ambient air

In the case of odour pollution, there is one clear advantage when working with citizen science. Humans are equipped with the best possible sensor to measure odours: our own noses. According to the IPPC H4 Horizontal Guidance for Odour, Part 1 - Regulation and permitting (UK Environment Agency, 2002), olfactory acuity (the ability to smell a certain odour) in the population follows a lognormal distribution, with 96% of the population having a “normal” sense of smell, as shown in Figure 1.

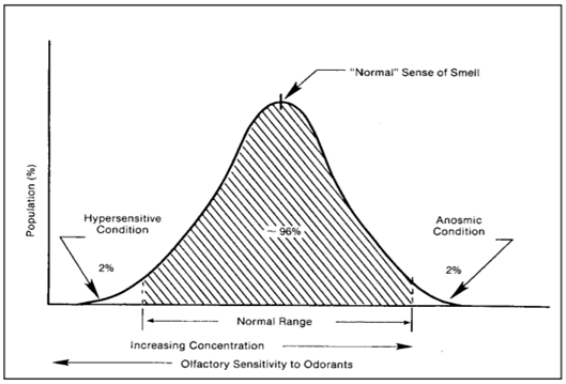

Figure 1: Diagram representing a frequency distribution of olfactory sensitivity (IPCC, H4, Environment Agency, UK, 2002).

Involving citizens in the processes of identifying odour problems, collecting data, interpreting the results and designing actions can significantly improve the way in which odour pollution is tackled, reducing the costs of measuring odours while empowering the communities. Previous European projects in the category of ‘Citizen Observatories’, focusing on Citizen science and environmental sustainability (such as Making Sense <http://making-sense.eu/>, CitiSense <http://www.citi-sense.eu/>, Omniscientis <http://www.omniscientis.eu/> on odour monitoring, CobWeb <https://cobwebproject.eu/>, WeSenseIt on water, WeObserve <https://www.weobserve.eu/>, etc.), have demonstrated that citizens can contribute to the identification -and potential solution- of environmental issues through collaborative data collection and analysis.
This is how the open data mobile App OdourCollect (<http://odourcollect.socientize.eu>) was born in 2016 after receiving funding from the European Project MyGEOSS, whose goal was to develop GEOSS-based (Global Earth Observation System of Systems) smart Internet applications informing European citizens on the changes affecting their local environment (<http://digitalearthlab.jrc.ec.europa.eu/app/57752>).

OdourCollect provides a tool to empower citizens, who are affected by regular odour nuisance, to report the incidence to the world. Odour maps are built based on crowd-sourced odour reports to calculate frequencies and levels of nuisance. Born as a citizen science experiment, any type of odour can be reported, also pleasant odours, at a worldwide level. In the first phase of usage of the App (current beta version), in which no specific promotion of the App or work with local affected communities have been performed, scattered observations have been collected, mainly in Spain, where the App has been created, although several observations in other countries such as Chile or Australia have also been recorded, as shown in Figure 2.

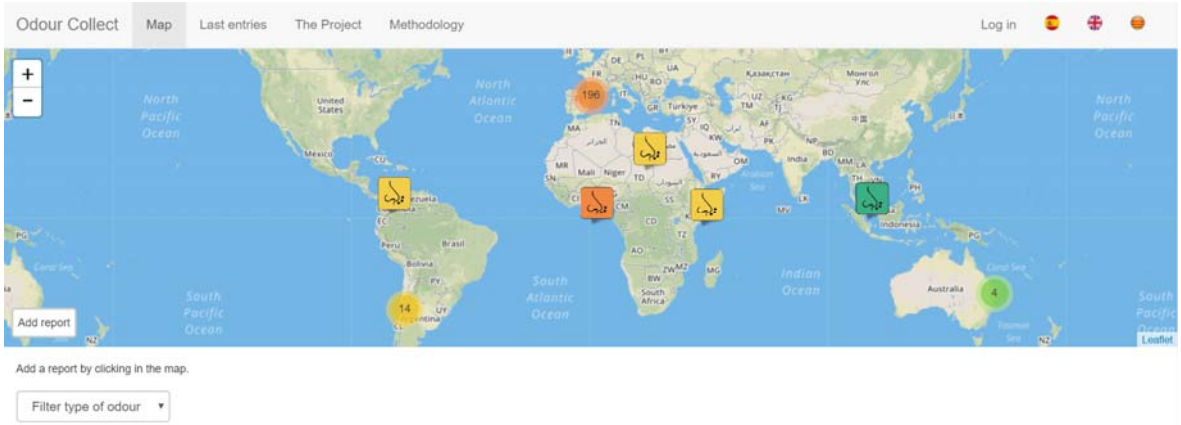

Figure 2: Screenshot of the current odour observations (open data) compiled in OdourCollect at global level. The beta version of the App is available in English, Spanish and Catalan and free to download for Android.

The system allows authenticated users to make comments on reports as well as to report odour episodes, including the following fields: Author (system), Place and time (system), Type of odour (to be chosen from a list or open field (e.g. garbage, sewage, chemical, other to be described, unknown), intensity from 1 to 6 (based on standard VDI 3882 Part 1: Determination of odour intensity), level of annoyance from -4 to 0 and to 4 (based on standard VDI 3882 Part 2: Determination of hedonic odour tone), weather conditions (only in the beta version; version 2.0 will integrate meteorological data in the local communities), origin (if known), episode duration (< 1min, 1-5 min, > 10 min) and comments. In order to add a new odour observation, a quick and unique registration process is required, in which statistical data is collected for analysis purposes (user name, user e-mail, password, age and gender), in which users are anonymised in compliance to GDPR. During registration and authentication process, the system ensures informed consent of users to reuse the data collected. All collected data is open data, meaning that anyone accessing the App or the website can see the global map, which can be filtered by period of time or odour types.
Data is collected using web and Android App forms in the Beta version of OdourCollect. Currently version 2.0 is being developed. The new version will allow access from any platform and will include a potent back office to analyse the gathered observations using reverse modelling with PROLOR to estimate the possible source of an odour complaint. PROLOR is a software based on a Lagrangian dispersion model run twice a day with a cluster of Linux machines with supercomputing capabilities (Díaz et al., 2016). The meteorology needed to estimate the back trayectory of the odour plume is obtained from 3D WRF (Weather Research Forecast) data. Topography and land use, together with WRF data are used as input to CALMET.
Inspired by the German standard VDI 3940 (2006) to measure the odour impact by field inspection, OdourCollect adapts the methodology with the aim of first identifying those areas of complaint where the quality of life is jeopardised by frequent odour exposure. Any citizen can act as observer and collect geo-localised open data on the odour episode, both in space and time, which can be used to build collaborative odour maps. All odour observations in an affected community will be validated by odour experts. In the case of nuisance, several observations of the same type of odour from several citizens in the same area and the same period of time, will validate the observation, whose origins will also be compared with the results obtained with PROLOR in the local affected communities. The resulting odour maps are open for public consultation and can be used to show the possible origin of the problem and ask for action to the relevant stakeholders, with the aim of reducing the nuisance, thus improving global sustainability and quality of life.

3. A new methodology for tackling odour pollution based on citizen science: The D-NOSES Project (Distributed Network for Odour Sensing, Empowerment & Sustainability)

Following the idea behind the citizen science tool OdourCollect, the H2020 European Project D-NOSES (<http://d-noses.eu/>), coordinated by the Ibercivis Foundation in Spain, with 15 partners from 9 countries,

aims to expand the reach of citizen science by developing tools and methodologies specifically designed for each local context to engage diverse groups of citizens –irrespective of their literacy or education level- in every step of the process, from the problem definition to data collection, analysis and actions, and building capacities. Data will be collected in The International Odour Observatory, a platform dedicated to promoting engagement at all levels, and literally putting odour pollution on the map. Citizens will join other stakeholders such as industries, local authorities and NGOs, in 11 pilot sites to co-design solutions to their odour problems. Community regulations will be encouraged so that citizens and local authorities can act as promoters of a bottom-up, multi-level governance model to be applied at local, national and global level.
From April 2018 to March 2021, and with a 3,1 M€ budget, D-NOSES will produce the Green Paper on Odour Pollution, and scientific and policy guidelines to pave the way for standardisation and definition of common odour impact criteria. Furthermore, the Strategic Roadmap on Odour Pollution will be produced to introduce the issue into the policy agenda in the medium to long term and help promoting sustainability through community action. The proposed methodology also achieves to implement Principle 10 of United Nations' Rio Declaration (<https://www.unenvironment.org/news-and-stories/story/unep-implementing-principle-10-rio-declaration>) in odour-conflicted communities. The proposed engagement strategies will foster public participation, the International Odour Observatory will guarantee access to information, and the advocacy actions will ultimately allow for access to justice, safeguarding the right to a healthy and sustainable environment for present and future generations in odour conflicted communities.

3.1 The D-NOSES Engagement Methodology

D-NOSES aims to improve on existing and previously validated engagement methodologies from project partners Ideas for Change (IFC) and Mapping for Change (MfC) through a comprehensive field evaluation of different methods. A combined approach will enable D-NOSES to create a reliable, replicable method that should be universally applicable in diverse regions and situations around the globe, to generate scientifically valid and actionable data through citizen science interventions that can improve people's lives.
The Bristol Approach (Balestrini et al., 2017), as developed by IFC, puts the concerns of citizens at the very heart of the process, helping local communities to co-design and implement citizen science based interventions around matters of concern in their living areas (odour pollution in this case), which lead to creative solutions and positive results, as shown in Figure 3. This ensures a high level of sustained engagement throughout the duration of the project, as citizens are prepared to give their time and energy to address matters that are relevant to the community.
The engagement model by MfC (Hacklay et al., 2018) is deliberately flexible to follow different pathways directed by discussions and needs of the local community, as shown in Figure 3. Guided by Principle 10, the model starts by introducing already existing and accessible information. Then it follows up with a facilitation process that supports communities to collect and share their own environmental data from citizen science observations. The generated data is then evaluated and improved in an iterative loop so that it can finally support the drive for change.

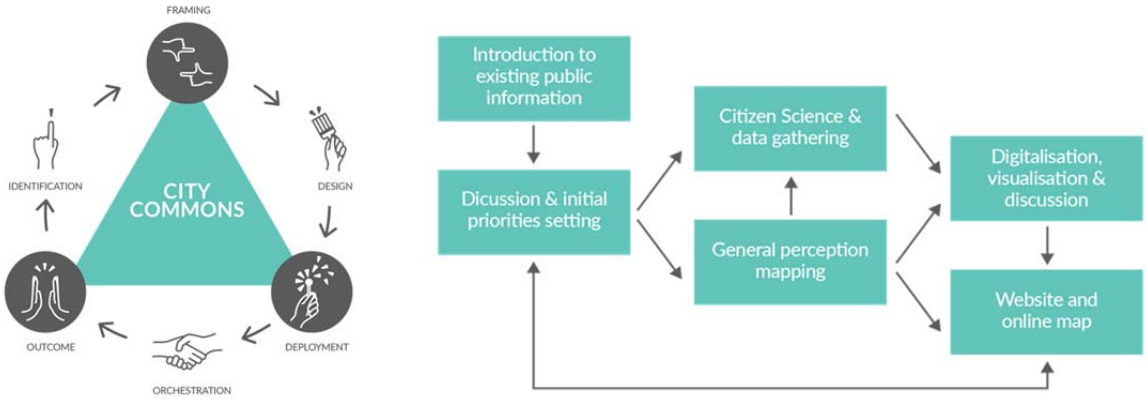

Figure 3: Diagram showing the two engagement approaches that will be used and combined during the implementation of D-NOSES: the Bristol approach by IFC (left) and the engagement model by MfC (right).

D-NOSES will combine both approaches to engage odour affected communities at local level, to test and validate the proposed methodology, using OdourCollect to compile odour observations. The Extreme Citizen Science Approach (Hacklay M., 2013) will be used to provide communities with a means not only to monitor their surrounding environment and to analyse their findings, but also to define the problem, co-design methodologies and tools that enable them to own, share, and act on their results. Our citizen science

interventions are intrinsically inclusive and apply all the Responsible Research and Innovation (RRI, <https://www.rri-tools.eu/about-rri>) dimensions, with a special focus on gender and science education, while using the quadruple helix approach in each local community to involve all relevant stakeholders.

3.2 Validating the methodology at international level: the 11 pilot case studies

In order to validate the new methodology, at least 5 communities per country (Spain, Italy, UK, Germany, Greece, Portugal, Bulgaria and Chile), plus two extra countries to be selected, preferably outside Europe will be engaged in co-creation workshops, from which 11 local communities (1 per country, except Portugal, where two communities are involved) will be chosen to perform citizen science interventions for one year following the above-described methodology. For each selected community, the stakeholder map will be defined and, for each stakeholder identified, a study of the motivations for engagement, potential risks and barriers and mitigation strategies will be conducted. As a result, the best participatory strategy will be designed for each group of stakeholders within each community, and new monitoring tools will be provided when required. Six out of the eleven local communities have already been selected, to act as pioneer pilots and inspire the rest, including Barcelona in Spain, the Porto area and São João da Madeira in Portugal, Sofia in Bulgaria and two more communities to be defined in Chile and Greece.

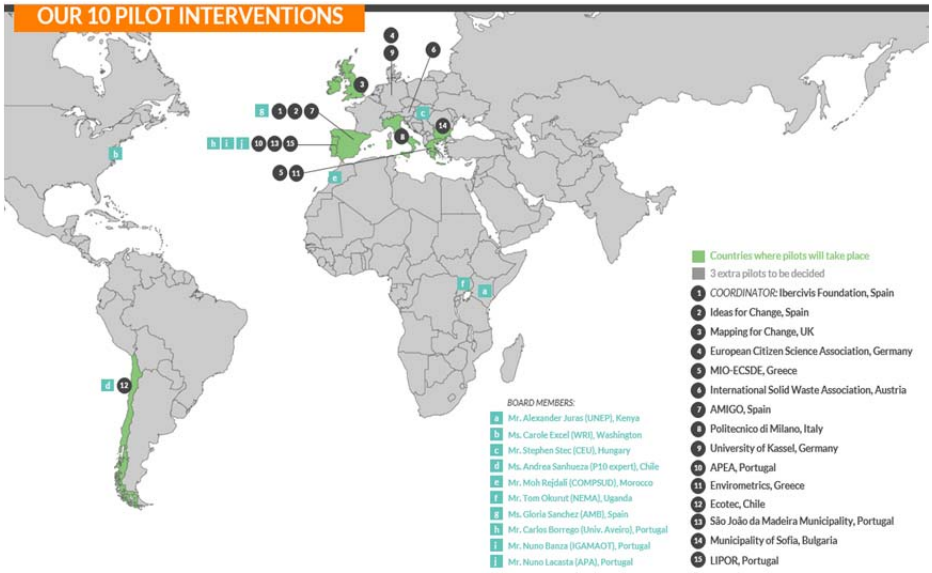

Figure 4: Locations of the partners of the D-NOSES Project and the Advisory Board members where the 11 pilot citizen science interventions will take place in local communities affected by odour pollution.

In each community, the engaged citizens will be trained by odour experts to make good quality odour observations and distinguish between the different types of odours, following the training methods described in VDI 3940:2006. In some cases, the selected community champions will be certified with n-butanol following EN 13725:2003, to guarantee a standard sense of smell. All observations will be validated by odour experts, with the help of the analysis tools, meteorological data and the PROLOR software to analyse the possible source of the odour impact, which are currently being integrated in the back office of OdourCollect 2.0. Bias will be identified and eliminated, and only the observations from validated users will appear on the open map. With the involvement of the emitting industries, operational data will be matched to the odour observations to identify key processes and non-favourable meteorological conditions that are mostly contributing to the nuisance, and improve the situation. Citizens providing the observations and local authorities will also be involved in the decision-making process, together with the odour emitting industries and the odour experts, in order to co-design *ad hoc* local solutions that can work for the local community, and are feasible to be implemented.

4. Conclusions

An innovative, bottom-up methodology is proposed to reverse the way in which odour pollution is traditionally managed. The methodology is based in an engagement model previously validated and a quadruple helix approach, to guarantee the involvement of the local authorities, the odour emitting industries, the Academia

and the affected citizens. From April 2018 to March 2021, and with a 3,1 M€ budget, D-NOSES will validate the proposed methodology in 11 pilot cases in 10 countries. Citizen science tools such as OdourCollect will be used to gather odour observations, which will be validated by odour experts, using reverse modelling (PROLOR) and matching the observations with industrial operations and local meteorology to co-design local solutions. Project results will be used to create DIY Guidelines for project replicability and storytelling techniques to disseminate D-NOSES successful cases. The evaluation of methodologies will allow to standardize methodologies, to provide scientific guidelines for policymaking, to write the Green Paper and the Strategic Roadmap for Governance in odour pollution, and to initiate advocacy actions to influence policies with the aim to introduce odour pollution in the policy agendas.

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