CHEMICAL ENGINEERING TRANSACTIONS

VOL. 85, 2021

A publication of AIDIC

The Italian Association of Chemical Engineering
Online at www.cetjournal.it

Guest Editors: Selena Sironi, Laura Capelli

ISBN 978-88-95608-83-9; **ISSN** 2283-9216

DOI: 10.3303/CET2185025

The Italian Pilot Study of the D-NOSES Project: an Integrated Approach Involving Citizen Science and Olfactometry to Identify Odour Sources in the area of Castellanza (VA)

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This work was developed within the Horizon 2020 D-NOSES project, with the purpose of validating a new methodology for odour pollution management based on citizen science. The work was carried out in the area of Castellanza, in the Region of Lombardy (Italy), and involved 4 plants that have been identified as potential causes for odour emissions. In this complex situation, it was proposed to combine the D-NOSES methodology with the "traditional" way involving olfactometric measurements and dispersion modelling, in order to identify the causes of the odour problem. The results of the olfactometric surveys allowed to identify the major odour emissions of the plants under investigation. Moreover, the preliminary analysis of the 358 odour observations collected in the period between May 14th and September 30th 2020 by a group of trained citizens, resulted in the disprove of the common belief that a particular product of the chemical plant caused the release of odorous chemical substances generating malodours at the municipal WWTP.

1. Introduction

The overall aim of the H2020 D-NOSES project is to develop and validate a methodology for odour pollution management based on a bottom-up approach, which uses participatory strategies for citizen involvement, engagement with a broad set of quadruple helix stakeholders, and the co-creation of practical and balanced solutions.

Within the frame of this project, 10 pilot studies are being carried out in 10 different countries in order to develop and validate the methodology. In the case of Italy, the pilot study involves 3 small Municipalities located in Northern Italy: Castellanza, Olgiate Olona, and Marnate, comprising a total of ca. 35'000 inhabitants. In the area between these Municipalities, an odour problem has been lamented for years. A non-organized collection of complaints started already in 2016: the number of complaints clearly shows that there is an unsolved (a non-identified) odour problem on the territory.

As a first step of the project, 4 plants were identified as potential sources of the lamented odour nuisance: a chemical plant, the municipal WWTP, a textile and dyeing industry, and the WWTP connected to the dyeing industry. For the purpose of investigating the cause of the odour nuisance, it was decided to adopt an integrated approach, involving the new D-NOSES methodology with the "traditional" top-down approach involving olfactometric measurements and dispersion modelling (Capelli et al., 2011), as it is foreseen by the specific guideline about odours of the region of Lombardy (Regione Lombardia, 2012), where the 3 Municipalities are located.

More in detail, this work presents the first part of the study, involving the olfactometric measurements on the odour sources of the four plants and a first preliminary analysis of the odour observations collected through the App Odour Collect, an open-source tool developed within the D-NOSES project.

Paper Received: 27 January 2021; Revised: 4 March 2021; Accepted: 26 April 2021
Please cite this article as: Lotesoriere B.J., Giacomello A.D., Bax C., Capelli L., 2021, The Italian Pilot Study of the D-noses Project: an Integrated Approach Involving Citizen Science and Olfactometry to Identify Odour Sources in the Area of Castellanza (va), Chemical Engineering Transactions, 85, 145-150 DOI:10.3303/CET2185025

2. Materials and Methods

2.1 Description and history of the site

The Italian pilot is being carried out in an area comprising three small municipalities located in the Region of Lombardy: Castellanza, Marnate and Olgiate Olona. At the beginning of 2019, the Majors of the 3 Municipalities contacted the Politecnico di Milano because their citizens have been complaining about the presence of malodours for years. Indeed, this part of the Region is highly industrialized: in particular, based on the provenance of the odour complaints and the prevalent wind direction, four plants have been firstly identified as potential sources of odours in the study area. Those comprise a chemical plant, the municipal WWTP, a textile and dyeing industry, and an industrial WWTP connected to the dyeing industry.
Historically, there has been a long-lasting debate regarding the chemical plant and the municipal WWTP, involving the belief – not supported by scientific evidence – that a particular product of the chemical plant causes the release of odorous chemical substances in their wastewaters, thereby generating the presence of malodours at the municipal WWTP, which receives them for treatment.

Figure 1: Location of the Italian pilot

2.2 Proposed methodology

Although no national regulation about odours exists in Italy, in 2012, the Region of Lombardy issued a guideline, paving the way for addressing odour pollution problems (Bokowa et al., 2021). The guideline is divided into different phases: phase A is the systematic monitoring of odour complaints, in order to verify the presence and the entity of the odour problem; this (in 2012) was foreseen by involving citizens through the use of questionnaires. In practice, phase A is very rarely applied. On the other hand, phase B, is applied in most cases: this phase involves the quantification of odour emissions by means of dynamic olfactometry according to EN 13725:2003 and then odour impact assessment by dispersion modelling (Cusano et al., 2010).
For this reason, in this complex situation, in order to find an answer to the main research question: “What is causing the odour problem?”, it was proposed to combine the application of the D-NOSES methodology involving extreme citizen science with the “traditional” way involving olfactometric measurements and dispersion modelling. This approach, besides respecting the local guidelines, also has the advantage of providing scientific sound experimental data to validate the D-NOSES methodology, allowing to cross the results of the dispersion modelling studies with the odour observations by the citizens, in order to identify the odour provenance.

2.3 Collection and analysis of odour observations

The odour observations from the citizens were registered through the app and website OdourCollect (https://odourcollect.eu/), which have been developed within the D-NOSES project. The app allows users to indicate whenever an odour is perceived by providing its type, intensity, and hedonic tone. The location of the perception is registered automatically by using the geo-localization system of the device where the app is installed (smartphone, tablet or PC).Even though the app is open source and any user may add observations after registration and login, in this case, it was decided to “train” a group of volunteers on how to make a complaint, with the purpose of increasing their sense of responsibility in the participation to the project. The observations made by these trained users are the one that, in a first period, are being used for further analysis and for comparison with other data (e.g., meteorological data and dispersion modelling results).
A first public meeting with communities was held on the 10th December 2019, during which a general introduction of the D-NOSES project and its objectives were presented, aiming to inform citizens about the future activities and find volunteers for the project.
The training of the volunteers was organized in three subsequent meetings.
The first training took place on the 20th January 2020, and over 50 people attended, which was considered a huge success. During this meeting, the methods that can be used for odour impact assessment were explained, thereby focusing on citizen science and on its potential to become an effective tool for managing odour problems. Then, citizens were further engaged in framing the problem by asking them 4 questions:

1. Do you feel annoyed by odours?
2. Are odours perceived more frequently on specific hours, days, or seasons?
3. Which type of odour do you perceive more frequently?
4. What are your expectations from the project?

The answers to these questions were collected on specific anonymous forms, and their analysis allowed us to get a first overview of the problem, as perceived by the citizens.
The second meeting (11th February 2020, 42 participants) was a “practical” workshop. The aim of this training was to make citizens familiar with the concept of odour and its main characteristics through some examples. For this purpose, the citizens were asked to smell 7 different odour samples and to fill a table describing intensity, quality, and hedonic tone of the perceived odours on suitable scales. The samples that were used for the training were: n-butanol at 4 different concentrations (ranging from 60 ppb to 15 ppm), Dimethyl disulphide (DMDS), Guaiacol, and Vanillin. These samples were prepared as to be representative of different intensity levels, different odour types, and different degrees of pleasantness.
A last meeting was organized on the 14th May 2020 online (due to the COVID-19 pandemics public meetings were forbidden) to explain how the app works and officially start the collection of observations from the citizens.
This paper refers to the first 4.5 months of observations, i.e. those collected between the 15th May and the 30th September 2020. The observations collected during this period underwent a preliminary analysis, with the aim to highlight the existence of specific correlations, for instance with the plant operations or with the meteorological conditions. For this purpose, some tools of the statistical analysis were employed, such as the chi-squared test (Franke et al., 2012).

2.4 Identification and quantification of odour emissions

A deep inspection of the 4 plants under study was carried out in July 2020, with the purpose of analysing the process and identifying all the potential odour sources to be characterized by dynamic olfactometry in the subsequent phase.
Odour emissions were quantified in terms of odour concentration and odour emission rate (OER) according to EN 13725:2003. Samples were collected at the sources according to the methods describe in the Regional guideline (Regione Lombardia, 2012), on different dates in July, September and December 2020 in order to characterize different operational conditions of the plants. Olfactometric analyses were carried out at the Olfactometric Laboratory of the Politecnico di Milano within 30 hours after sampling.
In order to evaluate the results of the olfactometric analyses it should be mentioned that the Regional guideline fixes a lower limit of 80 ou_E/m^3 and 500 ou_E/s below which an odour source can be considered as negligible for odour impact assessment purposes.

3. Results and Discussion

3.1 Olfactometric analyses

Textile and dyeing industry
The textile and dyeing industry has 2 main conveyed emissions, related to the bleaching and the drying of the tissues. The odour concentrations measured in correspondence of these emissions were >80 ou_E/m^3: 910 ou_E/m^3 for the bleaching, and 460 ou_E/m^3 for the drying of the finished tissues. The corresponding OERs are 270 ou_E/s and 1600 ou_E/s, respectively. However, in order to evaluate the impact of those emissions, it should be considered that the company is not operative at full load: the emissions are active a few hours a day (ca. 5) for max. 5 days a week, making that their overall impact can be considered as negligible.

Industrial WWTP connected to the dyeing industry
The industrial WWTP is located close to the textile industry and treats about 1000 m^3/day of its wastewaters. Moreover, it is authorized to treat a maximum of extra 90 m^3/day industrial wastewaters coming from other activities (e.g., landfill leachates, wastewaters of galvanic industry). The treatment tanks are all open, except for the small chemical-physical pre-treatment tanks for the industrial wastewaters, which are opened but located under a shed, closed on 2 sides. The only non-negligible odour emissions are the ones from the homogenization tank (with an odour concentration ranging from 130 ou_E/m^3 in winter to 1200 ou_E/m^3 in summer) and those from the chemical-physical reaction tank (ca. 20’000 ou_E/m^3 in both seasons). However, due to its small surface of 3.5 m^2, the OER of the latter is just close to 500 ou_E/s.

Chemical plant
The chemical plant produces 2 different products. One of them is produced discontinuously, and its production has been suspected for some time to be related to the presence of malodours on the surrounding area. For this reason, the olfactometric survey was planned when this specific production was active, in order to get an overview of the worst-case scenario.
The odour concentration measured in correspondence of the main emission of the plant, which is a chimney conveying all the emissions from the plant process units, is equal to 510 ou_E/m^3, which coupled with an airflow

of 12'000 Nm^3/h results in an OER of ca. 1800 ou_E/s, and is thus not negligible. Also, the concentration measured at the vent of the wastewater equalization tank, at the outlet of an activated carbon filter, which is equal to 650 ou_E/m^3 requires deeper investigation.

Municipal WWTP

The municipal WWTP treats ca. 22'000 m^3/day of wastewaters, out of which 30-40% have an industrial provenance, and the rest (60-70%) are civil wastewaters. 1000 m^3/day (i.e. ca. 4.5% of the total) are coming from the chemical plant under investigation. Most of the wastewater treatment tanks are closed into sheds or covered, except for the secondary sedimentators and the final disinfection tank, which however contain the depurated water, which is typically non-odorous. However, the air from the sheds and the covers is currently not sucked and treated in dedicated abatement system, thus originating potential diffuse odour emissions from the shed openings.

Table 1 reports the results of the olfactometric analyses carried out on the plant main odour sources, which correspond to the wastewater arrival and the first treatment phases. Two different conditions are clearly distinguished: a) a first condition of low odour emissions, with odour concentration values in the range of dozens or hundreds of odour units (July and December 2020), and b) a second condition with measured odour concentration values being at least one order of magnitude higher (September 2020). This variability cannot be explained by the meteorological conditions, since the campaigns of July and September, which were both characterized by high temperatures (> 30°C), produced very different results. Also, the common belief regarding a correlation between a specific production by the chemical plant and the increase of odour emissions at the WWTP is not supported by these results, since the "incriminated" production was active during all the olfactometric campaigns.

Table 1: Summary of the olfactometric results on the main odour sources

No.	Source	c_{od} [ou_E/m^3] July 2020	c_{od} [ou_E/m^3] September 2020	c_{od} [ou_E/m^3] December 2020
1	Wastewater arrival	45	18000	64
2	Wastewater fine screening	380	37000	3100
3	Sand removal	20	6500	860

3.2 Preliminary analysis of the odour observations collected until 30th September 2020

The total number of observations registered during the evaluation period (14 May – 30 September 2020) is 358.

Following the answers provided by the citizens during the first training, a first evaluation was performed in order to verify if the observations were more concentrated in specific days of the week or in specific times of the day (Figure 2). It is possible to observe that almost the half (48%) of the observations were registered in the evening hours, between 6 PM and 10 PM (time slot TS IV). Moreover, a preliminary analysis of the wind directions shows that about 60% of the odour observations are compatible with the location of the municipal WWTP.

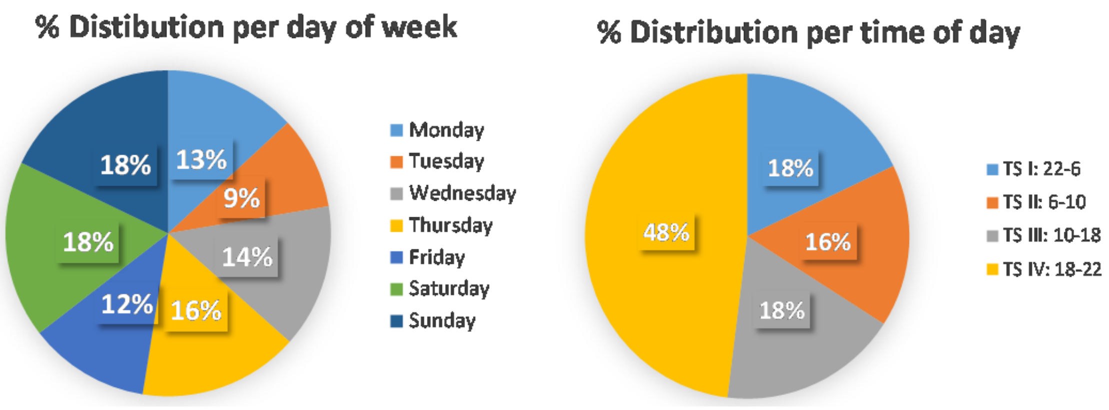

Figure 2. Distribution of the odour observations among days of the week (left) and times of the day (right)

In order to deepen this preliminary analysis, it was decided to apply the chi-squared test. To evaluate the difference between the collected data, it is possible to refer to an empirical rule: the difference is statistically significant if, with $p<0.05$, the calculated residuals are >1.96 (absolute value).
As an example, this test was applied in order to evaluate the distribution of the odour observations between the different times of the day compared to the reported intensity, obtaining a p-value of 0.037, thus indicating the existence of a statistically significant difference between those categories. The analysis of the standardized residuals (Table 2) shows that there is a statistically significant increase of observations having intensity 5 in the evening hours (TS IV), whereas there is a statistically significant lower number of observations of intensity 6 during the morning hours (TS II).

Table 2: Calculation of the standardized residuals for the extended chi-square test comparing time of the day vs. intensity of the odour observation

Intensity	1	2	3	4	5	6
TS I: 22:00 – 06:00	-1,0275	-0,7438	0,8179	0,8391	-0,8726	-0,2428
TS II: 06:00 – 10:00	1,2314	1,0250	-0,0736	0,7354	-0,5589	-2,3397
TS III: 10:00 – 18:00	1,0237	1,0751	0,8179	-0,8650	-1,6832	0,6532
TS IV: 18:00 – 22:00	-0,9052	-1,0010	-1,2002	-0,5226	2,3722	1,4107

A further evaluation was carried out in order to verify the existence of a correlation between the productions of the chemical plant and the occurrence of odour episodes. To do this, the number of observations was plotted against the concentration of aldehydes in the wastewater of the chemical plant (Figure 3), which are measured continuously, because the presence of aldehydes in the wastewaters of the chemical plant is related to the specific production suspected to cause odour problems.

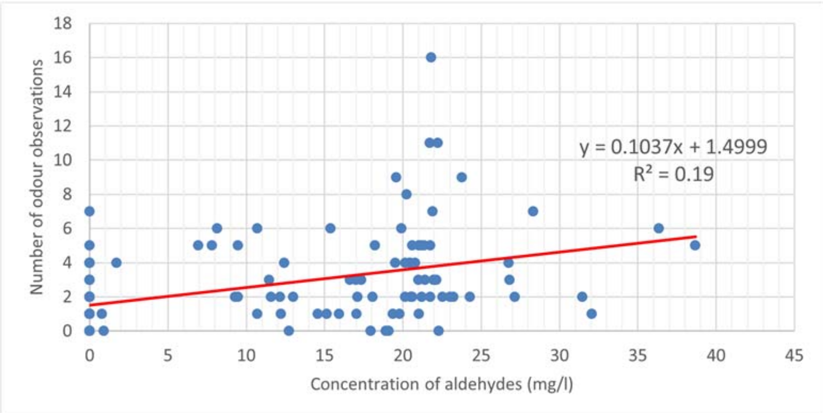

Figure 3. Analysis of the correlation between the number of odour observations and the concentration of aldehydes in the wastewaters of the chemical plant on a daily basis

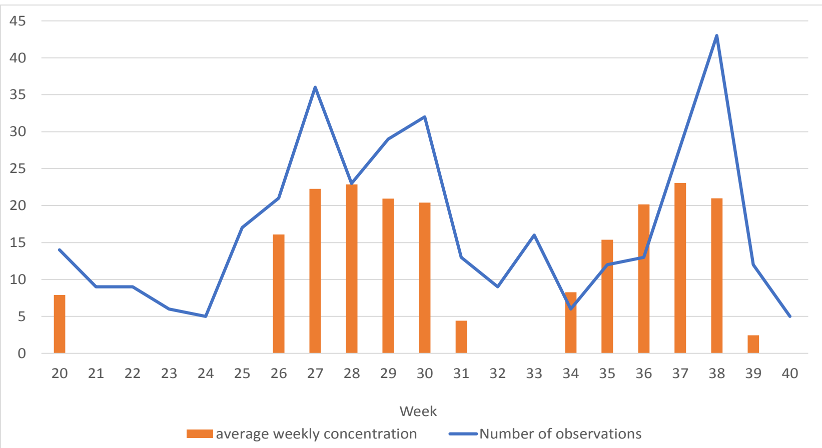

Figure 4. Number of odour observations and average concentration of aldehydes (mg/l) in the wastewaters of the chemical plant on a weekly basis

As can be seen from the trend line and the value of the correlation coefficient R^2 reported in Figure 3, there is no correlation between the two investigated quantities, meaning that there is no two-way correlation between the activities of the chemical plant and the presence of malodours on the territory. Indeed, there are several situations in which the production at the chemical plant was active, but no odours were reported by the citizens, as it was for instance the case during the first lockdown period in March and April 2020. However, if the same analysis is carried out on a weekly basis (Figure 4), a certain correlation can be observed: during the weeks with a higher number of odour observations, the production at the chemical plant was active.
This unexpected behaviour could be explained by the presence of another contributing factor, which has not been identified yet, which, together with the wastewaters of the chemical plant, causes the generation of intense and unpleasant odours at the municipal WWTP.

4. Conclusions

This study, carried out on 4 plants located close to the city of Castellanza, in Northern Italy, involved the execution of olfactometric analyses for the quantification of odour emissions and the collection of odour observations by trained citizen, with the aim to answer the following research question: “What is causing the odour problem?”.
The results of the olfactometric surveys carried out in different seasons have allowed to identify and quantify the major odour emissions of the plants under investigation, and the preliminary analysis of the odour observations collected in the period between the 14th May and the 30th September 2020 has allowed to draw some important conclusions regarding the causes of the odour nuisance.
Considering the meteorological conditions, it was observed that about 60% of the odour observations are compatible with the location of the municipal WWTP.
Moreover, it was possible to disprove the common belief that a particular product of the chemical plant causes the release of odorous chemical substances (i.e. aldehydes) generating malodours at the municipal WWTP.
Therefore, the reason for the odour nuisance on the studied area could be related to another not yet identified contributing factor, which, when getting in contact with the wastewaters of the chemical plants, causes the generation of intense and unpleasant odours at the municipal WWTP.
Future work should focus on the simulation of the dispersion of the odour emissions from the 4 plants and on the comparison of the outcomes of the dispersion modelling studies with the odour observations by the citizens, in order to identify the odour provenance. Further studies are also needed in order to identify the unknown factors causing the increase of the odour emissions at the municipal WWTP entrance, which has been verified both by olfactometric analyses and by the preliminary analysis of the citizens’ odour observations.

Acknowledgement

This project has received funding from the European Union’s HORIZON 2020 research and innovation programme under grant agreement No 789315.

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