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Atmospheric Odours: Monitoring of an Urban Waste Operator with Citizen Participation

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Environmental odours have a great amount of complexity because they are not considered as pollutants by having low levels of detection and concentration. They may cause impacts in population quality of life, by generating nuisance and discomfort. This situation may be more harmful with the existence of an urban agglomeration nearby an emission source.
The Human nose can quickly detect odours that individuals are subjected, but the interpretation and verbalization are very difficult to make.
Assessment techniques were used with quantitative and qualitative forms in two monitoring campaigns, one in summer and other in winter. This dynamic was held in a case study in a community with an urban waste treatment operator in which the surroundings make individuals perceptions of “rotten cabbages/rotten eggs” kind of odour.
The Observers Panel (OP) monitoring last 92 days with 137 odour records in which 65% were from the kind of “rotten cabbages/rotten eggs”. Hydrogen sulphide (H_2S) samplers results assured extremely low concentrations below the emissions limit value (5 mg/Nm^3), with 0.3 µg/m^3 average concentration in the summer period and 1.0 µg/m^3 in the winter time.
In the second monitoring campaign, the possibility of the “rotten cabbages/rotten eggs” kind of odour to be perceived by the sensitive receivers was very high due to the OP and the H_2S concentrations results. This was even higher in the locations of the OP were near the emission source. The weak dispersion conditions in this campaign led to higher concentrations levels of H_2S.
The dispersion model results indicated that, on the analyzed days, the odour plume had dispersed to the locations where the sensitive receptors made their assessments.

1. Introduction

Odours have a chemical structure and a diverse concentration, being no more than an organoleptic attribute that, by the inhalation of volatiles compounds, are perceptible for the human nose. This mixture is odoriferous because of the stimulation of the human smell. So, the perception of odours to the sensitive receivers, is an acknowledge of the effects of a sensorial stimulation that can change from one individual to another and by meteorological factors, environmental surroundings and the proximity to the emission source, not being directly related with the concentration of the odoriferous compounds (EN13725:2003). There are some factors that can enhance the development of odour complaints such as: the intensity and quality, the durability and frequency that it occurs, the time of the day that it happens, the dispersion of the compounds depending on the weather conditions, and the receiver characteristics (psychologic factors or the association with health risks) (Nicell, 2009).Sometimes, this olfactory inconvenient is considered by individuals as an indicator of odour pollution and unhealthy environment. This statement is even more reasonable as the exposure to odour emissions tends to be more frequent and could origin some physiological symptoms such as respiratory problems, nausea, eye irritation, among others (Sucker, 2009). The odour emissions tends to be more valued from an environmental and social point of view. In addition, the surroundings of the emission source, could affect the population and its social context with loss of properties values, loss of commercial activities and economic disadvantages.

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Having the odour annoyance and the subsequent impact on life quality of the neighbors of an urban waste operator as the two main focus of this study, a bilateral and complementary approach (qualitative and quantitative) was developed (Capelli et al, 2013). In one hand, the qualitative approach, gathered a group of citizens, with odour complaints, living nearby the emission source, called Observers Panel (OP), and the aim was measuring the discomfort. In the other hand, the quantitative approach was the determination of the concentration of the hydrogen sulfide compound (H_2S) that was primarily identified in ambient air with colorimetric tubes, for the determination of an odour marker. The odour threshold was very low, but perceptive to the human nose, so there was actually a problem that had to be solved using, besides a scientific explanation, a citizen intervention, with a community-driven research. This kind of strategic methodology that uses the citizens as assessors promotes the ability to endorse the role of people, giving them the possibility of monitoring their own odour exposure and producing data from that experience that will contribute to the analysis of the problem (Averett, 2017).
The quality of the citizen data had to be verified by the scientific team by making a comparative analysis with meteorological data, with registered complaints, with the consistency of the registers of the OP and with field inspections.

2. Experimental

2.1 Site description

The case study was conducted in the surroundings of an urban waste treatment plant (UWTP) in the Lisbon Metropolitan Area, Portugal. The industrial operator has a solid waste anaerobic digestion plant (SWADP), an Eco center, and a wastewater treatment plant (WWTP). The SWADP has the treatment ability of 75,000 t / year and some of the biodegradable matter is transformed in biogas and used to produce electric energy which is injected in the Nacional Power Grid and in a digested mud stabilized which origins composting for arboreal agricultural use. The WWTP processes residual waters with high pollutant load using a three-phase system that enable the decrease of the pollutant effluent by removing the inert load: removal of large solids, biological treatment and ultrafiltration and effluent adjustment for the further utilization in the productive process and washes.

2.2 Legal Framework

There are no legal odour limit values fixed in Portugal, because there are not proven negative impacts in human health and in the environment besides the nuisance. At the European level, the EN 13725: 2003:" Air quality. Determination of odour concentration by dynamic olfactometry" give a guideline to a standardization of the method for the objective determination of the odour concentration using dynamic olfactometry. So the portuguese scientific community in this type of case studies has to combine this European Standard with the reference legislation of other countries like Germany. So, the VDI 3940:2006 2nd part (Determination of Odour quality and Intensity) and the VDI 3883:1993 (Odour Nuisance Evaluation applying surveys), the UK Guide for Odour Management and the FIDOL system served as inspiration and guiding line for the qualitative and sensorial assessment used in the present research. As a specific compound in ambient air is being analyzed, the portuguese emission limit value for the hydrogen sulphide (5 mg/Nm^3) was taken into account.

2.3 Odour Sampling

The monitoring of hydrogen sulphide (H_2S) was performed by using the Radiello passive samplers for a 15 day period in two different campaigns (hot and cold season) in which the cartridges where left in shelters installed in trees and public lightening poles at a height of 2 m (a representative height for the simulation of the pollutant inhalation of the exposed population) reacting in ambient air (Ubilla et al, 2016). This samplers will provide information of the H_2S concentrations in a spatial distribution area and are interesting to use for a long time (Godoi et al, 2018).
The sampling grid was composed of nine points for each campaign which were located on the surrounding area of the urban waste plant and primarily chosen based on control circuits made to determine some odour focus. Two points were adjusted from one to another campaign due to the need of obtain the concentrations closer to the emission source and to establish a comparative analysis between these and the other grid points and records of the OP. This adjustment also allowed to verify the H_2S dispersion level in ambient air in the study area. Thus, two of the measuring points were placed inside the urban waste plant, one near the WWTP and the other near the SWADP, locations that can be considered possible odour focus. This way, it was possible to establish a comparison between the measurements on site and off site.
To enable the sampling analysis and the other methodologic elements, the meteorological description study was relevant for verifying the processes of atmospheric dispersion. The meteorological factors most influent in air quality and odourific dispersion are the wind velocity and his main direction, the temperature and the atmospheric stability. To allow this analysis, a weather station was installed at the study area.

2.4 Odour Measurements

2.4.1 Observers Panel (OP)

For the qualitative form an Observers Panel (OP) was assembled, a group of people with no link between them or to any industrial operator (causing odours) and with the common point of regularly perceiving atmospheric odours that cause nuisance. Nevertheless the sample had to have individuals that lived or work at least one year on the municipality. This group was submitted to an exploratory survey of their perceptions with analysis dimensions of odour like: kind, frequency, duration, pleasantness, intensity and level of nuisance (Brancher et al, 2014).Two samples were selected, one for each monitoring campaign and the group task was to mark the odour events on a standard registration form. This data were, afterwards validated with a weather station and with an atmospheric dispersion model (HYSPLIT-The Hybrid Single Particle Lagrangian Integrated Trajectory Model, developed by NOAA's Air Resources Laboratory, used for atmospheric trajectory and dispersion calculations) with the modeling of the emission source plume. This two groups were geographically distributed in locations near and far from the urban waste plant, to enable the determination of the atmospheric odour dispersion.

The main purpose of the OP was to daily register the odour events on their homes/work locations in a form previously distributed for that purpose. The OP was also regularly monitored by the scientific team with weekly interactions (e-mail, phone or face-to-face) and field visits to ensure the quality of the "measurements" and to make sure that the volunteers did not forget their task.

The data from the registration forms were carefully analyzed and the days with more events of "rotten cabbages/rotten eggs" (the perception of odour corresponding to H_2S) were compared with the meteorological factors and studied with the air quality dispersion model, with the purpose of visually tracing the extent of the odour plume, trying to understand its trajectory and atmospheric dispersion and perceive its range to sensitive receivers. By applying this methodology it is possible to empower the community (using citizens as scientists), listening to their worries and complaints and use the information that they gathered to try to find a way of coexisting with a malodourous industrial activity.

2.4.2 Measuring the odour impact with a field inspection

The lack of odour legislation in Portugal and the need of analyze the impact of the dispersion of the odour plume became essential to introduce the VDI 3940:2006 - 2nd part relative to field inspections. This measurement was made with the scientific team elements where the individuals evaluated the ambient air each 10 seconds in a measuring cycle of 10 minutes. Considering the terrain orography of the area and the H_2S grid for the passive measurement three intersection lines were defined according to the predominant wind (Sówka, 2010).

3. Results and Discussion

3.1 Quantitative Measurements

Figure 1 shows the H_2S sampling grid used for this odour assessment study. The results of the two air monitoring campaigns are presented in Table 1. The highest concentrations in the 1st campaign were measured in the sample point P2, while in the second one was the located in the WWTP (P12). Comparing the two average concentrations, the second campaign has the highest one. This can be explained by the fact of the relocation of the samplers P11 and P12. Excluding this two points as outliers, especially P12, there is still a higher concentration of H_2S in the second campaign. It stands out that this second measurement was in a cold season. In terms of meteorological elements, the analyses of the collected data showed that there was not a relevant difference in the average temperatures in the cold and hot campaigns (18.2 ºC and 17.1 ºC). The wind was predominantly blowing from the North direction (84% of the measuring period in the first monitoring and 64% in the second one), with higher intensity in the first campaign (3.2 m/s), which led to favorable atmospheric dispersion conditions compared to the second one (0.7 m/s). This could explain the higher concentrations of H_2S measured in the second period of monitoring.

In the end, it was observed that the sample points near the UWTP were the ones with highest concentrations of H_2S. Despite this fact, it is clear that the values are lower than the LEV defined in the Portuguese legal framework for atmospheric emissions. This can mean that the exposure of the population to this reduced levels of concentration is not offensive. Comparing this results with the odour threshold defined for the analyzed compound (nuisance reported to be in the ranges 0.7–200 µg/m^3) according to the World Health Organization (WHO, 2003), the levels measured in ambient air during the first campaign would not be detected by the human nose. However, given the fact that the passive samplers work by chemical adsorption for the exposure period of time and that the measures results are an average for the total period, it will not be possible to detect the concentration variations such as higher values to the referred detection limit. According to the results of the second campaign, as showed, the concentration of six of the nine points were above the odour threshold.

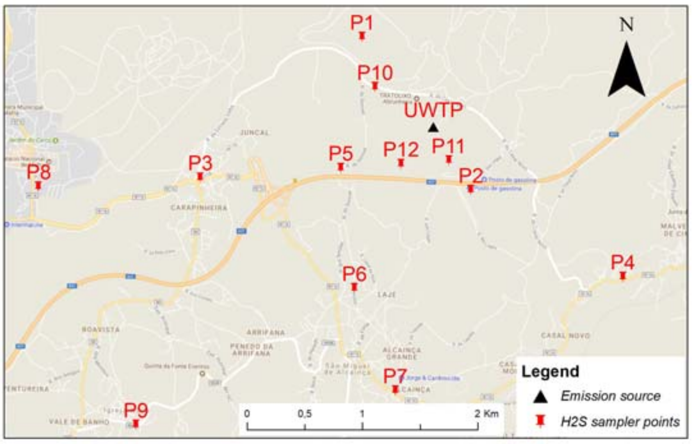

Figure 1 - H_2S grid and concentration results from the passive sampling monitoring

Table 1 – H_2S sampling results

Hydrogen Sulphide Concentrations (µg/m^3)		
Sample Period	06-06-2016 23-06-2016	24-10-2016 08-11-2016
Sample Points	1st Campaign	2nd Campaign
P1	0.2	
P2	0.6	0.9
P3	0.2	0.6
P4	0.2	
P5	0.2	1.4
P6	0.3	1.0
P7	0.3	0.7
P8	0.2	0.5
P9	0.2	
P10		1.3
P11 (SWADP)		1.6
P12 (WWTP)		114.4
Average	0.3	13.6

3.2 Qualitative/Sensorial Measurements

To measure the odour nuisance two groups of volunteers were assembled, which allowed to obtain registration forms of odour events. It is possible to see in Figure 2 an indication of the borderline locations from where the citizens made their observations. The two OP, measured a total of 92 days, and produced 137 odour records. In 35% of the sample period of the OP, there weren´t any records, so, the rate of odours perceptions was 65%. This records where mainly of the kind of “rotten cabbages/rotten eggs”. The evaluation of the level of odour intensity made by the citizens was classified as “moderate”.

The data from the OP showed that, in some days, different observers, from different locations made simultaneously the same kind of odour records (“rotten cabbages/rotten eggs”). In addition, the elements located near the plant in study, perceived more frequently the “rotten cabbages/rotten eggs” kind of odour.

This data were, afterwards validated with a weather station and an atmospheric dispersion model with the modeling of the emission source plume for the days with more records of “rotten cabbages/rotten eggs”. Using a hybrid model (HYSPLIT) with a dataset input of meteorological information, and with specific information of the urban waste plant (e.g., mass flow), was possible to simulate the dispersion plume of the emission source. On Figure 3, is illustrated one day with several records of “rotten cabbages/ rotten eggs” distributed in four different locations of the OP elements and the dispersion plume of the emission source. It is possible to see that the plume direction matches the locations of the OP elements, thus the OP records were validated. The result of the dispersion model allows to say that there is a significant odour impact on the sensitive receivers. In this same day, the wind direction and the dispersions conditions were also propitious to odour perceptions by the citizens.

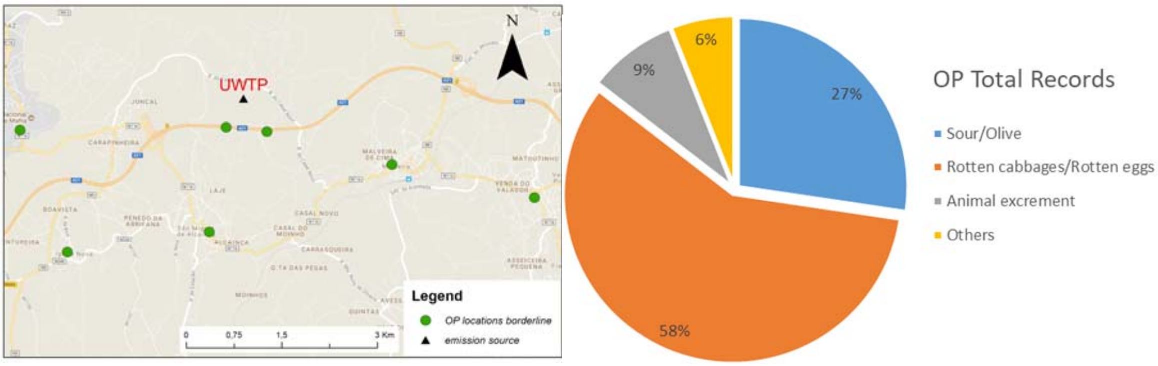

Figure 2 – OP borderline grid and total odour records

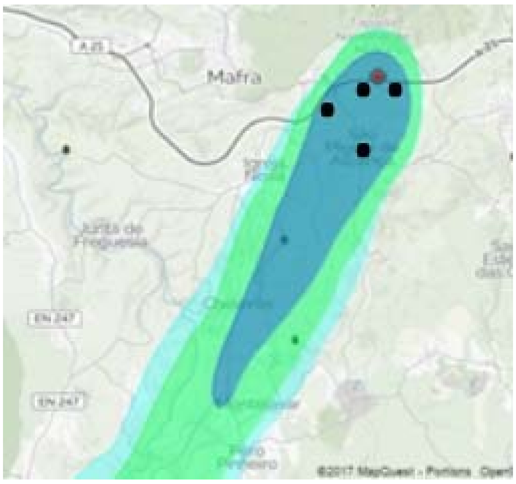

Figure 3 – Example of a Hysplit output with four OP locations

According to the VDI 3940- 2nd part, a pilot field inspection was made in the surroundings of the UWTP, distributed in a grid of 5 points with 3 intersected lines and favourable meteorological conditions such as wind blowing from north and with low intensity. This cannot be representative of the study but can give an idea of the odourific panorama in the field, and was the first step for future development of this case study.

The results showed that the “rotten cabbages/rotten eggs” odour was only detected in two points of the first and second lines of intersection. It was not detected any kind of odour than the referred one, or any odour in the farthest line considering the location of the emission source. The intensity level of the perceived odour was very weak.

4. Conclusions

This odour monitoring program tested a methodology where the main approach was the measuring of the atmospheric odours by involving citizens and the scientific team in a bidirectional relationship.

The results of the quantitative measurements led to conclude that que hydrogen sulphide concentration levels were higher in the second campaign, even when not counting with the relocation of two samplers on the UWTP area. The sampler near the SWADP presented a concentration in the same order of magnitude than the other ones and the sampler near the WWTP was the one with the higher concentration. It was possible, therefore, to ensure and verify the correct diagnosis of the determination of the odour source within the urban waste plant, as well as to establish a comparison between the proximity to the emission source and the surrounding area to the industrial activity.

In the second monitoring campaign a greater record number of the OP related to "rotten cabbages/rotten eggs" occurred, from which, comparing with the H_2S results indicate a higher probability of the odour to be perceived by sensitive receivers. This was also explained by the surpassing of the odour threshold level. The referred kind of odour was also more perceived and registered on the locations near the emission source. The weak dispersion conditions, associated with low intensity wind, gave rise to higher concentrations levels of H_2S and more records of the OP in the second campaign than in the first one. Also, the records of the OP were made mainly in the lack of wind or with moderate wind (especially blowing from north) and with clear sky or cloudiness. This means that strong wind originated a greater odour dispersion and, consequently, a decrease of the citizens' perceptions.

The dispersion model results demonstrated that, on the analyzed days, the odour plume had dispersed to the locations where the sensitive receivers made their assessments. Comparing the odour plume orientations with the prevailing wind directions, there was a coincident interaction, thus justifying the OP records. The odour perceptions in the field inspection were lower with the increased distance to the emission source.

Finally, it was possible to conclude that the methodology used for the monitoring program was adequate, having originated comparable results through the different approaches. Also, the citizens' participation in studies like this, is very important because it can improve the relationship between industrial operators or companies and the community, leading to complaints reduction and an acceptance attitude towards the odour nuisance. In addition, the industrial operators can also adjust their activity based on the data from the citizens, leading to an annoyance reduction and the consequent decrease of the odour impact on the receptors.

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