Environmental Odour Impacts from Factory Located in Sensitive Urbanized Area

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***Abstract*— Odours emitted by factories, like industrial complexes, have become a major concern for local authorities because the resulting annoyance in the neighborhoods. Chemical characterization of emissions is not applicable for the assessment of the impacts on citizen exposed to environmental odours emitted by specific factory. This paper describes the methodology adopted for assessing the odour impact on sensitive area generated by old factory located in the city center. The combination of olfactometric analyses with other in field techniques is presented and discussed for the evaluation of potential odour impact on the surrounding areas. Results discuss and compare different approaches to assessment odour impacts in urbanized area.**

***Keywords* — Annoyance, Air Quality, Environmental Impact, Exposure assessment, Odours, Olphactometry.**

I. Introduction

Odours have been ranked as one of the major generators of public complaints to regulatory agencies in North American and European communities (Leonardos, 1995) and they may represent the limiting factor for the construction of new plants (Schlegelmilch et al., 2005). The public usually reacts to objectionable odorous episodes by registering complaints with the local authorities (e.g., municipal by-law officers, police, and fire or health units), regional government agencies, and/or the personnel associated with an odour-emitting operation. The extent of this problem is evident from complaint statistics collected over a number of decades. For example, the United States National Research Council Committee on Odors (1979) estimated that more than 50% of the complaints related to air pollution deal with exposures to odours. More, an analysis of the 25 responses to a survey of regulatory agencies in the USA indicated that in 1994 more than 60% of air pollution complaints were related to odours with an estimated total of over 12.000 registered complaints (Leonardos, 1995). In many jurisdictions, odour impacts are regulated under the nuisance provisions of common law. However, the explicit conditions that establish whether a nuisance condition exists are not easily defined. Due to this shortcoming, methods need to be developed to objectively access the impact of odours so that odour-producing facilities have a proactive means of reducing their impact on surrounding communities (Henshawa et al., 2005). Even thug it is universally recognized that the exposure to odours generally represent a nuisance more than a risk for human health (Fransses et al., 2002; Luginaah et al., 2000), odour exposure may nonetheless cause effects on human activities (Gostelow et al., 2001; Shusterman, 1992). Prolonged exposure to foul odours can generate undesirable reactions ranging from emotional stresses such as unease, discomfort, headaches, or depression to physical symptoms including sensory irritations, headaches, respiratory problems, nausea, or vomiting (National Research Council Committee on Odors,1979). Exposure can also lead to psychological stresses and symptoms such as insomnia, loss of appetite and irrational behavior (Gostelow et al., 2001).While individual responses to odours are highly variable and can result in a variety of effects, generally the impacts of odours arise from a variety of interacting factors, collectively known as FIDOL: frequency, intensity, duration, offensiveness, and location (Nicell, 2008). The techniques available for odour nuisance characterization and quantification are substantially of three different kinds (Gostelow et al., 2001):

- Analytical: chemical analyses;
- Sensorial: dynamic olfactometry, survey by questionnaires;
- Senso-instrumental: electronic nose.

Analytical techniques allow to determine the qualitative and quantitative composition of a gas mixture using suitable separation and identification techniques, e.g. gaschromatography coupled with mass-spectrometry (GC–MS) (Davoli et al., 2003). Sensorial techniques, such as dynamic olfactometry (EN 13725, 2003) and survey by questionnaires, use the human nose as a sensor. Dynamic olfactometry, in fact, is a sensorial technique that allows to determine the odour concentration of an odorous air sample relating to the sensation caused by the sample directly on a panel of opportunely selected people. In addition to olfactory properties there are several factors that may influence odour perception. The most important one is the variability of human olfaction between different subjects. With this technique this problem is minimized by using a panel composed by several examiners, selected with precise criteria in order to have people with a standardized olfaction. With the dynamic olfactometry the odour concentration is measuring in OU/m3. The number of OUs in a sample represents the number of times the odorous gas must be diluted with odor-free air to reach the point where it elicits a response from just 50% of the population. It represents, then, the number of dilutions with neutral air that are necessary to bring the odorous sample to its odour detection

Manuscript received October. 13, 2016. This work was supported in part by the FARB project of University of Salerno.

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threshold concentration. Thus, when an odor is present at a level of 1 OU, the concentration is equal to that of the threshold. The analysis is carried out by presenting the sample to the panel at increasing concentrations by means of a particular dilution device called an olfactometer, until the panel members start perceiving an odour that is different from the neutral reference air. The odour concentration is then calculated as the geometric mean of the odour threshold values of each panellist. As defined by the EN 13725 (2003), the individual threshold estimate is defined by the two presentations in one dilution series, sorted on growing odour concentration, where a certain change in response from "false" to a consistently "true" response occurs. The individual threshold estimate is calculated as the geometric mean of the dilution factors of the two defined presentations. (Sironi et al., 2009). About the use of sociological investigations by the administration of questionnaires to measure the perception of the environment there are many references in the international, but only very few studies concern the monitoring of odors into the atmosphere. The German standards VDI 3883, Blatt 1 and Blatt 2, and VDI 3940 are a very useful reference for the formulation of questionnaires of odour survey for the input. This analysis tool is only used to determine the levels of odour input, or discomfort felt at the targets. Senso-instrumental techniques use artificial noses, which perform instrumentally the functions of human olfaction. Electronic noses are complex systems with a human nose like structure (Pearce, 1997). Currently, the Italian legislation does not set limits to odour emissions in the atmosphere and it does not regulate the methods and parameters to assess the level of nuisance odors. However, about the emissions there are studies and European Community standards and international reference about the methods for characterization, such as dynamic olfactometry and gas chromatography with mass spectrometry (GC-MS). While about the input of odour into the environment, only recently the interest about these problem is increasing and so there aren't regulations and standard methods to characterize them. This work discusses how it is possible to assess odour impact caused by input of odour into the urban environments.

II. Materials And Methods

A. Site description and monitoring network

The study was conducted on a city of southern Italy. The town is a very populated city and with an elevated lifestyle; her center, particularly, following the expansion of the population, it is found again, at the same time, to be also industrialized zone. This study was conducted by the application of three different odour characterization techniques, a survey by questionnaires in the whole area of monitoring to determine the most sensitive targets, dynamic olfactometry enabled to measure odour concentration and thereby to quantify the sensory impact of odours on points targets identified and a "questioning" survey with the aim of involving the population and making them actively take part to the odour impact assessment study by means of questionnaires for reporting the odour episodes on the territory. Finally, for a more complete evaluation of the results, these data can be linked with orographical and meteorological data. The latter were collected every day during the monitoring period on the whole area and in the days of air sampling on the points targets defined. This work represents a critical review of how three different odour assessment methods can be employed for evaluating the odour input into the urban environments. Through the critical analysis of the results it is possible on one hand to analyze the specificities of the three adopted odour characterization techniques and on the other hand to discuss the correlations between these techniques, showing that, whilst the results don't necessarily correlate, they do have an intrinsic value, and therefore demonstrating the complexity of environmental odour measurement. The experimental activity has concerned the monitoring of the zone of the railway station of the town. Initially, preliminary investigations have been effected to identify the characteristic odors of such area and their nature and origin. Then, by the first interviews with questionnaires to residents and passers-by were identified five points considered the most sensitive points of nuisance odours. The common factor recorded their responses referred to the typical odour of product by a specific industry, located near the station of that town. Morphological data have been collected to learn more about the area and to identify, according to the cardinal orientation of the building, the directions of wind currents which allow for greater dispersion of odors in the surrounding area. The representation of the map shows: the area of monitoring; the tobacco industry, one of the sources of odour emissions; the five target points, the points of odour input where have been performed samples of air.

B. Sample collection and olfactometric analyses

Ten odour sampling and measurement trials were conducted in order to characterize the odour input on five points identified. The trials took place from September 2010 to December 2010. To sample the odour input on five points has been used a long principle sampler made by ECOMA (D). The sampler (marca) has 685 mm long with a diameter of 152 mm. Sampling on five points is carried out by sucking part of the odorous airflow into an 3,5-L sampling bag in Nalophan (Wiesbaden, D) equipped with a Teflon inlet tube by means of a depression pump. An olfactometer model TO8 made by ECOMA (GmbH, D), based on the "yes/no" method, was used as a dilution device. All the measurements were conducted within 30 h after sampling, relying on a panel composed of four panellists.

C. Odor sensory investigations

Sensory analysis was achieved by the use of structured interviews. The objective of the administration of these questionnaires is to collect data and information about the perception of the population in respect of a nuisance odour inside the area. Two different types of questionnaires were administered, the first is based on the historical memory of respondents and was used to delimit the study area and to identify areas in which to sample, and the second is based on the sensation of smell perceived by passers-by in 'instant in which the sample is taken. The first questionnaire is defined Preliminary Survey Questionnaire because it was used to a preliminary survey of the all area of study and to identify the five sampling points. It was administered to 50 people about, including 25 women and 25 men, preferably, for each area, through direct interview face to face. The questionnaire was formulated following the German guideline VDI3883, it consists of two parts: one where was specified respondent's personal data and characteristics, sex and age, and a second part consists of questions mostly multiple choice questions. The questions concern: the perception of smells and sensation which is associated with this perception, the frequency, intensity, classification, identification of the source and finally was asked what the consequences are that they cause in respondent people.

The second questionnaire is defined Sampling Questionnaire because it was used when the sampling was made. It, also in agreement with the German guidelines, consists of two parts, one where was specified respondent's personal data and characteristics, sex and age, and a second part consists of 4 multiple choice questions. In all, in analysis preliminary, 54 questions were administered prior to the survey and 214 for the sensory analysis carried out in field simultaneously the sampling, at the points mentioned above.

D. Analysis of meteorological data

The collection of meteorological data was made with two different methods. In the first case, the meteorological data were recorded daily by a meteorological monitoring station, that is in Town. These data were recorded throughout the study area. In the second case, the collection of meteorological data was also performed in the field, every day of sampling, in each of the five points of regulation by an anemometer Kestrel 4000.

III. Results and Discussion

A. Definition of the monitoring network

The preliminary survey has allowed to define the monitoring network by means of a careful morphological study of the area, of meteorological data collected every day throughout the study area and of data processing results from the first type of questionnaire addressed to the local residents and passers-by.

The weather conditions greatly influence the dispersion of odor concentration in the atmosphere. There is a cause-effect relationship between meteorological variables and concentrations of odors emitted into the atmosphere. The wind carries the molecules and, depending on their intensity separates them longitudinally. The turbulent dispersion influences the characteristics of vertical motions of the fluid. It is generated by global warming, convective turbulence, and presence of relief and roughness, mechanical turbulence. It also depends on the speed, intensity and wind direction. The higher the wind speed, the greater the dispersion in the atmosphere. The meteorological data, that were recorded daily by a meteorological monitoring station, than, have been studied and elaborated. The wind rose, that is represented in Figure 1, shows the direction and intensity of the winds in this area during the period under review.

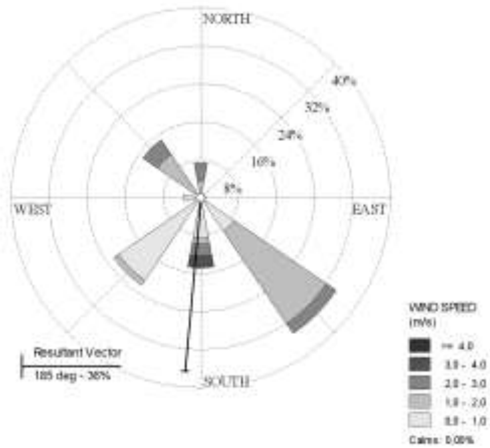

Fig. 1. Wind Rose (direction and intensity of the winds from September 2010 to December 2010).

From this representation it is clear that in this area blow mainly winds from south-west and south-east.

The first type of questionnaire has allowed to define the target-points of sampling. The data collected allowed the development of charts, some of which are shown in Figure 2. Were interviewed 54 people, including 27 women and 27 men, most of which falls in people aged between 26 and 35 years old. Each questionnaire, used in the preliminary analysis of odor perception, is composed by questions that refer to variables that influence the perception, summarized in the acronym FIDOL: frequency, intensity, duration, offensiveness, and location.

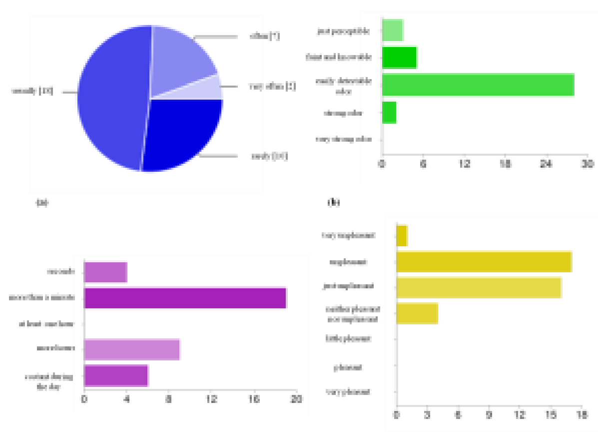

Fig. 2. Diagrams of odor perception: (a)-frequency; (b)-intensity; (c)-duration; (d)-offensiveness.

B. Field analysis

About the results of the olfactometric survey, which concentrations of odor were detected using a dynamic olfactometer TO8 (ECOMA GmbH, D) in according with EN 13725/2003, it was possible to obtain reference values in the threshold of perception felt by panel of evaluators selected. These values are representative of the mean threshold of perception of the population in the area. Figure 3 shows the distribution of concentrations with respect to the points where the samples were performed.

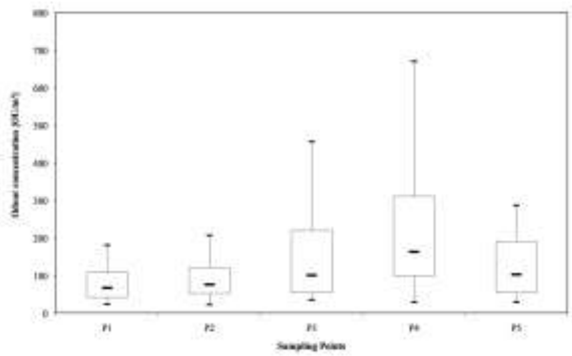

Fig. 3. BoxPlot of the Odour Concentration at different sampling points.

As you can see from the table the major geometric mean was in the second day of sampling in October 7, 2010. The temperature on that day showed values that ranged between 26 ° C and 29 ° C, while humidity ranged between 39% and 48%. In addition, in relation to the points where the samples were performed, the chart, referring to the 25°, to mean geometric and to the 75° percentile, shows that the point P4, located on the railroad bridge of the town, is one in which it was values higher concentration of odor. At that point, the higher concentration obtained from the analysis olfactometric is equal to 670 OU and temperature and humidity respectively of 26.3 ° C and 48.1%.

As before mentioned the collection of meteorological data was also performed in the field, every day of sampling in each of the five points of regulation. In an analysis of temperature and humidity data so obtained, the lack of correlation with the concentrations of odor measured is clear.

The second questionnaire is based on the odor noise perceived by passersby, at any target-point defined, when the sample was taken. It consists of two parts, one about personal details of the respondent and the second consists of 4 multiple choice questions. As the first type of questionnaire the second refers to the characteristics FIDOL, but in this case the frequency is excluded because the sensory measurement on the field was instantaneous. The data collected as a result of these interviews have enabled the development of charts below represent. 214 persons were interviewed, of which 116 are female and 98 male, most of which falls in an age range between 19 and 25 years old.

C. Correlation studies

Correlation studies were conducted between the odor concentrations, estimated by dynamic olfactometry, and the discomfort felt by the population, obtained through field survey, carried out by questionnaires, at first, throughout the monitoring area and at the points considered most sensitive target after. The statistical results obtained by sensory analysis, have been developed for the calculation of an index of odor sensory (Ios), calculated using the following equation:

$$\mathrm{Ios} = \sqrt[n]{\prod_{i=1}^{n} \mathrm{Ios,i}}$$

which Ios was calculated using two different formulas depending on whether it refers to the results obtained by Preliminary Survey Questionnaires or those derived from Sampling Questionnaires. For the results of the first the formula used is as follows:

$$\mathrm{Ios,i} = \mathrm{O} \times (\mathrm{I} + \mathrm{F} + \mathrm{E} + \mathrm{S})$$

where O is the perception of odour (0, no odour, 1 presence of odour), I is the intensity (scale of 1 to 5), F is the discomfort (on a scale from 1 to 5), E is the exposure (on a scale from 1 to 5), S represents the health problems (0, no disturbance, 5, this disorder). It was calculated for each survey conducted. The Ios,i , in this case, can therefore assume a value from 0 to 20.

For the results of the second type of questionnaire however, the formula needed to calculate Ios,i is:

$$\mathrm{Ios,i} = \mathrm{O} \times (\mathrm{I} + \mathrm{F} + \mathrm{E} + \mathrm{S})$$

As before, this index was calculated for all interviews and for each sampling point. In this case, however, Ios has a range from 0 to 15.

The concentrations of odour, that were measured in Odor Unit in the 5 target points for each sampling, were then compared with the indexes Ios. From analysis conducted it is seen that there isn't a strong correlation between the concentrations of odour and the indexes prepared by Preliminary Survey Questionnaires, otherwise there is a clear correlation between the concentrations and indexes, Ios, obtained with Sampling Questionnaires. Analyzing the latter correlation, in fact, you may notice that a higher concentration of odour involves a nuisance more. In this regard, 10 charts were developed as much as the sampling that were conducted. By them it shows that, in mean, the point P4, located on the railroad bridge of the town, is the point where this relationship is most evident and where, in addition, higher concentrations of odour occurred more frequently during this study period. The graphs below represent respectively: the correlation between the odour concentrations and indexes Ios obtained with Sampling Questionnaires and that refer to the 5 points defined and the correlation between the geometric mean of odour concentrations and the geometric mean of indexes Ios, always calculated with the second formula, referring to the all period of surveys at 5 point defined.

At point P4 we have reached values of odor concentration equal to 670 OU and this phenomenon occurred in correspondence with values of temperature and humidity respectively of 26.3 ° C and 48.1%. As with the concentrations of odour, with also the index of sensory odour it was shown that compared with the same physical factors, temperature and humidity, there are not clear correlations.

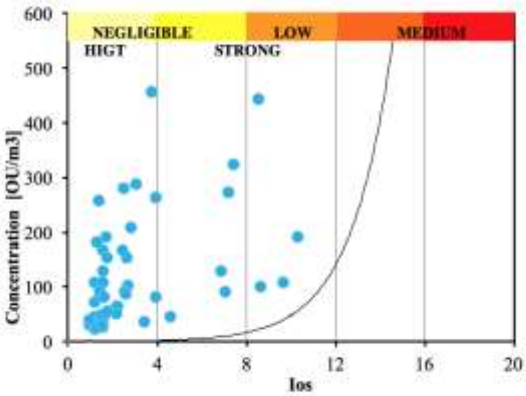

Fig. 4. Assessment of potential odour impact with reference to Ios and correlation with monitored odour concentration

Referring, finally, to existing study of correlation between the odour concentration, expressed in OU, with the Ios (Montemarano, 2010) and plotting the values, of this case study, of total concentrations of odour and the total reported Ios to those at each point for each sampling, it can be concluded that the impact from odour reaches the mean values and the Figure 4 show it. This band is one of five already defined in the work mentioned above, in which, as the range of IOS includes values between 0 and 20, the odor impact of an urbanized area has been divided into five classes: in the first negligible impact is defined, Ios = 0-4, in the second impact is low, Ios = 5-8, in the third impact is low, Ios = 9-12; in the fourth impact is high, Ios = 13-16; the last band is the one with a strong impact, Ios = 17-20.

IV. Conclusions

This study led to results that show the potential of the proposed methodology, based on sensory analysis and on dynamic olfactometry, applied in the town in the station area. The urbanized study area was identified from a geographical point of view, finding in it the main activities that produce odorous substances and any sensitive targets at which a preliminary survey was made to measure the perception of any discomfort of population. Subsequently, sensory studies on field and sampling of air were made, at several points from September to December, and then laboratory testing were made. Throughout the period of investigation and evaluation, the collection of the meteorological data was made because the climate directly affect the dispersion of odors. The data obtained from surveys carried out on site were examined and they allowed the development of an index of sensory odor, Ios. The results of surveys conducted on a sample of 300 individuals in adulthood and both sexes, compared with the data obtained from laboratory testing, revealed the correspondence between the different types of results.

The implementation of this procedure to assess the impact of odors to input in urban areas made possible, then, to get effective results in line with the proposed target. It was found that this actually there is the impact of odors in the area of the town. As assumed we have been able to verify that the main source of emissions is Tobacco Factory. The correlation between concentration and odor sensory index was significant and, as regards the influence of temperature and humidity index of sensory odor, it was negligible. This new methodology, inspired by the efficiency of field inspection and combining it with the dynamic olfactometry, has achieved these results in a shorter time and lower costs. In this context it is likely the opportunity to continue the future experiment even better to refine its application or to proceed with the same strategy over a longer period of observation, or otherwise evaluating the odour emissions in the same monitoring area for later comparison with results by odour input achieved so far. You can see, finally, that the scientific approach and experimental is helpful to ensure the detection of odours and its quantitative characterization. With an action to monitoring and verification of the potential impacts of odor to input on urbanized study area, infact, is possible to provide a useful and reliable analysis tool to institutions responsible for management and control of territory and to civil users in the analysis and in the resolution of disputes under this theme.

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