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Odour Impact Assessment by Community Survey

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Odours emissions that result from anthropic activities and may cause an adverse effect on health status, social and individual life are frequently classified as airborne pollutants and are subject to control and regulation. Atmospheric dispersion of unpleasant odours is considered one of the major causes of public complaints concerning air quality and represents a growing social problem in industrialized countries. Due to the need to protect population from possible olfactory nuisances from a food industry located in an urban area in Brazil, an odour impact assessment was conducted to evaluate the annoyance level by means of community survey. The study was carried out in the surroundings of the odour source involving local residents through administration of 395 standard questionnaires in a one-shot campaign. The area of investigation was divided into five sub-areas named Region 1, Region 2, Region 3, Region 4 and Region 5 within a radius of about 2 km centered in the facility. The questionnaire applied characterized basically the public interviewed, hedonic tone, intensity, frequency and period of the day that perceived odour episodes occurred. Annoyance level were compared with the criteria of ≤ 20 % 'at least annoyed' established by New Zealand Ambient Air Quality Guidelines, used as reference, for environmental compliance. Region 2 was the most impacted área by emissions from the facility presenting annoyance level of 31 % at least annoyed. Comparing the degree of annoyance (17 %) for all Regions with the criteria used as a reference (≤ 20 % at least annoyed), food industry is in accordance with maximum annoyance standard permitted. Community survey is a low cost methodology, compared to others methods, but it is difficult to insure impartial judgement in order to avoid errors in the responses. This technic can be satisfactorily used to asses odour impacts from facilities in urban areas taking into account past experiences, seasonal effects and the role of human perception through social participation.

1. Introduction

Odour emissions are capable of interacting with receptors, and thus has the potential to cause olfactory nuisances. Industries; including water and waste water treatment plants, intensive agriculture practices, food processing facilities and waste management operations have an environmental and social obligation to ensure they do not adversely affect the surrounding community during the discharge of their intended function (Parcsi et al, 2012). Several atmospheric pollutants, but mainly volatile organic compounds (VOCs), are responsible for the occurrence of odour episodes of varying annoyance levels. Detectable odours can affect moods and have psychological and physiological impacts on people's daily lives (Gallego et al, 2008).

Odours that result directly or indirectly from human activities and cause an adverse effect to human health, social and individual life are generally classified as pollutants and are subject to specific regulation by environmental agencies (Nicell, 2009). Olfactory nuisances related to odour emissions are considered a major cause of public complaints to the competent authorities in relation to air quality, and represent a growing social problem in industrialized countries (Blumberg and Sasson, 2001; Ranzato et al, 2012). Therefore, appropriate monitoring along with regulatory tools are necessary to prevent, control and mitigate the impact of odors in communities (Ranzato et al, 2012).

The impact of an odour results, generally, from a combination of interacting factors, collectively known as FIDOL: frequency (F), intensity (I), duration (D), offensiveness (O), and location (L). The FIDOL factors

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encompass the pattern of odour impacts and the receiving environment where these occur (Freeman and Cudmore, 2002; Nicell, 2009). Location is an essential factor when assessing the likelihood of adverse effects from odours. It accounts for the type of area in which a potentially affected person lives, the type of activity they are engaged in, and the sensitivity of the receiving environment. These factors determine the probability of a person being adversely affected to the point where they find an odour to be offensive or objectionable. The absence or presence of background odours also has a significant effect. The sensitivity of the receiving environment can generally be categorised according to land use (Freeman and Cudmore, 2002; Nicell, 2009). Annoyance potential is a proposed attribute to quantify the propensity of an odour to cause nuisance within a population when exposed to this odour intermittently, over a long period of time. Annoyance level is likely to be a function of both odour quality and offensiveness in addition to perceived intensity (UK Environment Agency, 2002). Odour nuisance issues are particularly worrying when more industrial activities exist near residential areas (Capelli et al, 2011). Due to the loss of sensitivity of habitants affected by unpleasant odors over time, intensity is a parameter that should not be assessed by questionnaire without prior training (e.g. calibration of the respondents with butanol).

Odour impact assessement studies can be conducted directely in field using, for example, trained assessors (human panel) according to VDI 3940 – Part 1 (2006). This method has become popular in some parts of the Europe and US. However, is thought to be time consuming, high cost and largely dependent on local meteorological conditions (Zarra et al, 2010; Naddeo et al, 2012). A diagnosis of air quality related to perception of odors within an area of investigation can also be conducted appling questionnaires in the surrounding community of the emitting source. From a general point of view, the odour exposure is always a human feeling. For this reason, social participation may be very useful for odour exposure assessment purposes (Capelli et al, 2013). Environmental impact assessment through field studies of ambient odors usually provides the following information: (a) compliance monitoring for assurance and permit renewal; (b) determination and assessment of the odour status of the area of investigation for baseline data for expansion planning; (c) identification of emitting sources; (d) verification of complaints; (e) comparison of operational practices for evaluation of alternatives; (f) assessment of weather-related episodes of odor; (g) comparison of odor reduction technologies; (h) characterize the population under study (McGinley and McGinley, 2000). Assessment by questionnaires generally measure population annoyance level due to all sources of odour (when there are more than one inside the area of investigation). The results can be used to classify odour sources according to their contribution to the cumulative stress within a community. A limitation of this technique concerns the application in areas with sufficient population density to achieve statistically significant results (New Zealand Ministry for the Environment, 2003).

In this context, due to the need to protect population of possible odour impacts from a food industry located in an urban area in southern Brazil, an odour impact assessment was conducted to evaluate the annoyance level by means of community survey.

2. Materials and methods

2.1 Area of investigation

The case study concerns a food industry manufacturer of additives and ingredients located in Southern Brazil. The area of investigation is an urban zone, surrounded by mountains with high population density. The area of investigation was divided into five sub-areas, established within a radius of about 2 km centered in the facility. These areas are here named: Region 1; Region 2; Region 3; Region 4; and Region 5. This range for target population was choosed based on reports of odours complaints received by environment agency and by studing the case. Extra questionnaires were administered separately in an area localized at a distance of about 2.5 km from the source as a control population. Figure 1 shows the localization of the area of investigation highlighting the source (food industry), the five Regions of study and the control population.

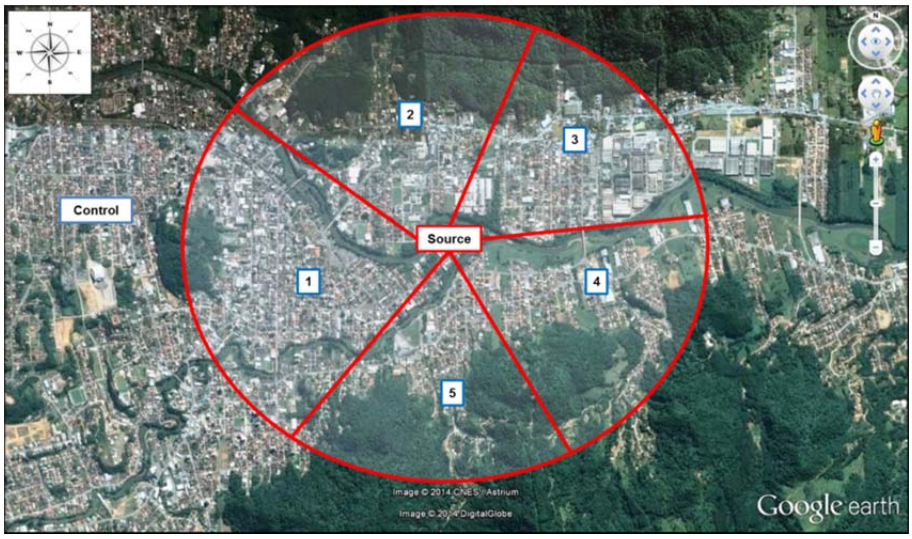

Figure 1: Localization of the area of investigation highlighting the source (food industry), the five Regions of study and the control population.

2.2 Survey sampling

To define the sampling plan and the number of questionnaires to be applied Eq (1) and Eq (2) were used, assuming a tolerable error of 5% (Barbetta, 2001):

$$\mathrm{n} = \frac{\mathrm{N} \times n_0}{\mathrm{N} + n_0} \quad (1)$$

$$n_0 = \frac{1}{E_0^2} \quad (2)$$

Where, n is the sample size; N is the population size; and E_0 is the tolerable error sample.

2.3 Structure of the questionnaire

The structuring and implementation of the questionnaire survey followed the instructions of the VDI 3883 - Part 1 (1997) and New Zealand Ministry for the Environment (2003), adapted to the brazilian reality and the specific case study here presented.

The questions aimed:

- characterize the respondents (proportion of men/women and age) while maintaining their anonymity;
- identify the emission source of odour;
- weather conditions (temperature, wind direction, period of day and season) related to episodes of exposure to odours from the food industry;
- Identify adverse symptoms on human health from exposure to food industry odours.

Survey respondents were also asked about annoyance levels they experience from odour. Responses were classified according to the scale in Table 1. The key statistic used from odour surveys is the 'percent at-least annoyed' category, which is made up of the responses ranging from annoyed to extremely annoyed (New Zealand Ministry for the Environment, 2003). Only the odour nuisance level associated with the food industry was assessed for enviromental compliance.

Table 1: Annoyance levels for odour community surveys.

Definitely not annoying	
Very little annoyance	
Little annoyance	
Some annoyance	
Annoying	Percent at least annoyed
Quite annoying	
Very annoying	
Extremely annoying	

The model questionnaire is of closed type with multiple choice questions, with its application performed in a structured way. Therefore, the respondent verbally answered the interviewer's questions that transcribed for the record. The poll is based on olfactory memory (past experiences) of the interviewee, reflecting their experience in relation to perceived odours in the area of investigation, and not its current condition at the time of interview. Thus, mechanisms of exclusion of respondents (e.g. flu, allergy, smoking) were not applied.

2.4 Environmental compliance

Environmental compliance of the food industry was referenced in the guideline criterion recommended for assessing survey results is ≤ 20 % 'at least annoyed' based on New Zealand experience from control populations (New Zealand Ministry for the Environment, 2003). Typical results from control surveys in New Zealand show that 5 – 15 % of the community report being ‘at least annoyed’ by industrial odours, even when there are no significant odours (Cudmore and Dons, 2000). The acceptable level of cumulative odour impacts is due to all odour sources. However, verification of facility compliance with current regulation was conducted by calculating the annoyance levels considering only the responses of odours identified as the origin of the food industry.

3. Results and discussion

3.1 Validation

The correlation between the magnitude of the impact and the area of investigation adopted was validated administering extra questionnaires for a control population. If significant odour was perceived at the control point, the coverage of the study should be set higher than 2 km. Control population presented a level of 2 % at least annoyed. According to New Zealand Ministry for the Environment (2003), level of less than 15 % at least annoyed indicates that the survey methods were correct.

3.2 Survey results

For a population of 29,867 inhabitants of the area of investigation, a minimum number of 395 questionnaires were calculated and applied. Of this total, 52 % of which were male and 48 % female, 43 % had age of 21-42 years and 14 % were smokers. Main data related to the part of the questionnaire which dealt with the perception, character, source identification, frequency, duration and annoyance of odours are summarized in Table 2. It is emphasize that the results of frequency, duration and annoyance were calculated only for the food odours to assess the food industry impact.

Table 2: Results of the community survey by region investigated.

Region	Perception	Character	Source	Frequency	Duration	Annoyance
1	70 % smell odours	57 % food odour	55 % food industry	19 % 1-3 times during the week	39 % hours	17 % at least annoyed
2	83 % smell odours	63 % food odour	57 % food industry	19 % 2-5 times during the day	49 % hours	31 % at least annoyed
3	72 % smell odours	34 % food odour	32 % food industry	14 % once a day	22 % hours	5 % at least annoyed
4	59 % smell odours	40 % food odour	37 % food industry	24 % 1-3 times during the week	23 % hours	9 % at least annoyed
5	52 % smell odours	16 % food odour	16 % food industry	12 % 1-3 times during the week	16 % minutes	0 % at least annoyed

As seen in Table 2, in all regions were reports of perception; Region 2 presented the higher proportion (i.e. 83 %). Some of the respondents answered smell other odours different from food odour, such as smoke and sewage, which are related to vehicular traffic and illegal connections to the storm sewer network, respectively. Main part of respondents connected the results of odour episodes with the food industry. Again, the Region 2 had the highest score reporting 63% of food odour with frequency of occurrence of 2-5 times during the week for 19 % of the respondents. It's also noteworthy the continuous emission of odours from the food industry, since odours are perceived for hours during the day in Regions 1, 2, 3 and 4. The community response to odor annoyance was 31 % and 17 % at least annoyed in Region 2 and Region 1, respectively. Therefore, the most impacted zone by odorus is Region 2, which presents individual annoyance level higher than that permitted by New Zealand Ministry for the Environment (2003) of ≤ 20 % at least annoyed. Symptoms reported by the population were headache, restlessness and nausea.
Periods of perception, weather conditions, season and wind directon related to episodes of food odour are summarized in Table 3. Regarding the perception, afternoon was the period of the day considered with higher perception. Most respondents said that the perceived odours are independent or did not know to define the season and weather conditions. The response of wind direction were used to validate the results of respondents' answers regarding the emission source. All wind directions reported in the Table 3 are downwind of the source, which makes sense with the position of the regions with the food industry.

Table 3: Results of the community survey by region investigated.

Region	Periods of perception	Weather conditions	Season	Wind direction
1	16 % afternoon; 14 % night	25 % independent; 20 % don't know	27 % independent; 22% don't know	37 % E
2	30 % afternoon; 17% all day	30 % independent; 20 % don't know	26 % independent; 20 % don't know	42 % SSE
3	9 % night; 7 % afternoon	20 % independent; 8 % don't know	21 % independent; 9 % don't know	29 % SW
4	22 % afternoon	25 % independent; 7 % don't know	27 % independent; 6 % don't know	29 % NW
5	8 % afternoon; 4 % night	8 % independent; 4 % don't know	12 % independent; 4 % don't know	16 % N

3.3 Summary of results

Table 4 summarizes the main results for all regions considered in the assessment. For Regions 1, 2, 3, 4 and 5 considered in the study, 69 % of the respondents claimed smell odours with 48% reported the quality is food odour; 45 % connected the this odour with the food industry located in the area of investigation. The odour annoyance level observed was 15 %. Comparing this result with the guideline criterion used here as reference, food industry would meet the license permit renewal.

Table 4: Summary of main results for all regions under study.

Sample	Respondents	Perception	Character	Source	Annoyance
Regions 1, 2, 3, 4 e 5	395	69 % smell odours	48 % food odour	45 % food industry	15 % at least annoyed

Conclusions

In view of the need to protect population of possible odour impacts from a food industry localized in an urban zone with high population density, in southern Brazil, an odour impact assessment study was conducted to evaluate the annoyance level by means of community survey. In this sense, this study verified the presence of odorus from the food industry in all five regions evaluated. More specifically, the results showed that 69% of the respondents claimed smell odours, with 48 % reporting the quality is food odour and 45 % conecting the odour with the food industry located in the area of investigation.
As Brazil still does not have specific regulations for environmental odours, compliance was referenced in the guideline criterion recommended for assessing survey results is ≤ 20% 'at least annoyed' established

by New Zealand Ministry for the Environment (2003). The odour annoyance level observed was 15 % at least annoyed. Thus, food industry would meet the license permit renewal considering the entire area of investigation. However, it is noteworthy that Region 2 is highly impacted by presenting, individually, a value of 31 % at least annoyed. Symptoms caused by food odours reported by the population were headache, restlessness and nausea.

Accordint to the results of the study, it was possible to highlight some points about the methodology used and the possibility of using this technique as a tool to protect population from odour impacts. Community survey is a low cost methodology and a fast technique to be applied, compared to others. However, it is difficult to insure impartial judgement in order to avoid errors in the responses. This method can be satisfactorily used to asses' odour impacts from facilities localized in urban areas presenting such advantages as take into account past experiences, seasonal effects and the role of human perception through social participation. As pointed out, cooperation of citizens may be very practical for odour exposure assessment purposes since exposure to odours is a human emotion.

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