

Case study: Odour annoyance assessment in the vicinity of an anaerobic digestion plant in the Lisbon area - test of the revised Guideline VDI 3883

Anália Torres¹, Filipa Vaz¹, Maria Inês Baeta Neves¹, Markus Hangartner², Kirsten Sucker²

¹Valorsul, S.A., Department of Studies, Quality and Information (DEQI), Lisbon, Portugal;

²Institute for Environmental and Process Engineering (UMTEC) at the University of Applied Sciences, Rapperswil, Switzerland

In order to assess the impact of odours in the vicinity of a biodegradable waste processing plant, previous odour exposure measurements were completed by an annoyance study according to the draft of the revised Guideline VDI 3883/Part 1 (2009). The extent of odour annoyance was assessed by direct interviews in four survey areas and one control area in November 2009. The households were randomly selected and after quality inspection 120 valid questionnaires, 21 to 27 in each survey area were obtained. The questionnaire, covering odour annoyance, symptom reporting and relevant covariates, was developed according to the latest findings from odour and noise annoyance research.

Results showed that 67 (56%) residents in the survey area did not perceive any odours at all. Only 14 (12%) residents perceived the plant odours. Only in Zone A, where the perception of plant odours was most likely, a moderate annoyance level was found. Concerns relating to possible overestimation of odour annoyance were reflected. Implementing a worst-case and a best-case scenario, annoyance due to all odours perceivable in the residential area or to plant odours only was assessed. To complete the picture, the influence of other environmental stressor (noise and electromagnetic pollution), and possible non-olfactory factors like age, education, and length of residence, were tested by means of analysis of covariance.

The results showed that the combined effect of exposure due to odour and noise triggers the annoyance reaction, particularly in Zone A. However, residents were not concerned about possible health effects due to electromagnetic pollution. Furthermore, it was shown that residents with a problem-focused coping style react more sensible to odours in the residential area. As a conclusion, odour abatement measures at the plant will reduce community annoyance reaction only to a small extent. Other annoyance sources like noise pollution have to be tackled too. With regard to the residents, who show a problem-focused coping style, the communication strategy, already started in 2006, may be an effective measure.

1. Scope

Valorsul (www.valorsul.pt) is the company responsible for the treatment of waste from the metropolitan area of Lisbon (Portugal). The integrated waste management system of Valorsul consists of five units: a municipal solid waste processing plant (CTRSU), a materials recovery facility and collection centre (CTE), a sanitary landfill (AS), a bottom ash processing and recovery plant (ITVE), and a biodegradable waste processing plant (ETVO). Each year about 800 000 tonnes of waste are processed by the system. Due to complaints from the neighbourhood in the vicinity of ETVO, a strategic plan for elimination of odours was developed based on two types of complementary approaches: technical and communicational (Vaz et al., 2009).

In terms of the technical approach, two odour monitoring campaigns were implemented before and after taking optimizing measures (Vaz et al., 2008; Torres et al., 2008). The results of the second campaign confirmed that odour emissions were still above the aspired limit. Consequently, a study to measure odour impact by field measurement followed by the development of an atmospheric dispersion model was implemented.

In respect to the communication strategy, in the beginning of 2006 an Accompanying Group (AG) was constituted by representatives of the municipality, one representative from a nongovernmental organisation, three persons from Valorsul and one person from the technical university. In order to follow the plant construction and operation, to inform about measures taken by Valorsul to mitigate the odour impact, to discuss and be aware of technical problems and solutions, and to forward this information to community, meetings take place monthly. One of these communicational tools is the implementation of the program "Sentido Apurado" Team that was an idea developed by Valorsul that involves a group of citizens who live or work near the plant that are voluntaries with the task of registering the odours they believe that come from the plant. Other actions like for example an information newsletter distributed in the near neighbourhood, weekend visits of residents, and a web page that reports on the meetings of the AG, complement the communication strategy.

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2. Aims

Based on results of dispersion modelling the odour exposure area was defined. In order to frame the survey area the following information was gathered: location of neighbourhood complaints, cursory inspection of the area to check if other environmental exposures (e.g. noise, electromagnetic pollution) are dominant, if the housing structure is homogeneous, and if sufficient households exist. From this area four survey zones were determined as well as an additional control zone with zero odour exposure. The survey zones were selected according to the following criteria:

- Zone A: The perception of Valorsul odours is very likely, uniform house building structure: pre-dominantly one or two floors, approximately 30 years old
- Zone B: The perception of Valorsul odours is likely, uniform house building structure: predominantly one or two floors, approximately 30 years old

- Zone C: The perception of Valorsul odours is unlikely, uniform house building structure predominantly four floors, approximately 4 years old
- Zone D: The perception of Valorsul odours is very unlikely, uniform house building structure: predominantly four floors, approximately 20 years old
- Control zone: The perception of Valorsul odours is totally unlikely, separated areas with uniform house building structure: one with predominantly one or two floors, approximately 50 years old; the other with predominantly four floors, approximately less than 5 years old

The extent of odour annoyance was assessed by direct interviews in November 2009 with a standardised questionnaire. The questionnaire, covering odour annoyance, symptom reporting and relevant covariates, was developed according to the latest findings from odour and noise annoyance research (Guideline VDI 3883/Part 1, draft, 2009). Core elements of annoyance assessment were the annoyance thermometer, an 11-point graphic scale (Hangartner 1988; Cervinka and Neudorfer, 2004), and the internationally standardized 5-point verbal annoyance scale (Felscher-Suhr et al. 2000; Fields et al. 2001). Comparison of the annoyance ratings on both scales was used to judge the quality of an interview. Strong deviation between the ratings showed that the consistency of responding (reliability) is questionable and the interview was omitted.

3. Results

Out of the 376 distributed letters in total 136 interviews were obtained (response rate: 36%). In studies on odour annoyance, response rates vary between 29% and 43% (industrial odours) and 18% and 40% (agricultural odours) (Sucker et al., 2009). The response rate in this study was 36% and laid at the upper end of response rates typically obtained in survey studies on odour annoyance.

After quality inspection 120 valid questionnaires, 21 to 27 in each survey area remained. The graphic and the verbal scale revealed good correspondence ($r = 0.94$, $N = 120$, $p < 0.001$). The determination coefficient ($r^2 = 0.88$) was higher than 0.80. This showed that the plausibility of the data is sufficiently high (Rammstedt, 2004).

Results showed that 67 (56%) residents in the survey area did not perceive any odours at all. Only 14 (12%) residents perceived plant odours. Other odours perceivable in the survey area were caused by garbage, sewer system, landfill, and other sources (e.g. neighbours). In Zone A, where the perception of plant odours was most likely, a moderate annoyance level was found (Table 1).

Table 1 Evaluation of the odour annoyance situation in the survey area

| Degree of annoyance | Zone A (n = 22) | Zone B (n = 27) | Zone C (n = 26) | Zone D (n = 21) | Control (n = 24) |
|--------------------------------|--------------------|--------------------|--------------------|--------------------|---------------------|
| Worst case: All odours: | | | | | |
| Average annoyance | 3.7 | 2.3 | 2.4 | 2.1 | 1.3 |
| Extremely annoyed (≥ 8) | 9% | 11% | 12% | 10% | 0% |
| Best case: Plant odours | | | | | |
| Average annoyance | 1.5 | 0.1 | 1.3 | 0.6 | 0 |
| Extremely annoyed (≥ 7) | 18% | 0% | 12% | 5% | 0% |

In order to reflect concerns relating to possible overestimation of odour annoyance, a worst-case and a best-case scenario was implemented.

In the worst case scenario, based on the Swiss approach of odour annoyance assessment and evaluation (Swiss Agency of for the Environment, Forest and Landscape (1989) Fundamentals of Odour Evaluation, Report No. 115), annoyance is assessed due to all odours perceivable in the residential area. Furthermore, the percentage of "extremely annoyed" persons, i.e. those who classify their level of annoyance on the graphic scale as being above ≥ 8 , is likewise determined. Reviewing a number of studies conducted in the vicinity of odour-emitting industrial plants it was found, that the 10% proportion of extremely annoyed persons is reached at an average value of 3 on the annoyance thermometer, and the 25% proportion is reached at an average value of 5. The evaluation takes place on the basis of the Swiss Noise Abatement Ordinance. The Noise Abatement Ordinance specifies an emission limit value of 60 dB(A) and an alarm limit value of 70 dB(A) for residential zones during the daytime. If these noise limit values are viewed in the context of the number of extremely annoyed persons, approximately 10 percent of those affected feel extremely annoyed when the emission limit value is reached, and approximately 35 percent when the alarm limit value is reached. Therefore, the evaluation scheme for odour level applied in Switzerland (Table 2) states that an odour level is tolerable and no particular measures have to be taken, if the annoyance thermometer score is below 3 and the percentage of extremely annoyed persons below 10%. It is medium and long term measures have to be taken, if the degree of annoyance is between 3 and 5, and the percentage of extremely annoyed persons between 10 to 25%. If the annoyance score is above 5 and the percentage of extremely annoyed persons above 25%, the odour level is rated as excessive and immediate measures are necessary.

Table 2 Evaluation scheme for odour level applied in Switzerland

| Odour level | Degree of annoyance | Percentage of highly annoyed persons | Measures |
|-------------|---------------------|--------------------------------------|------------------------|
| Excessive | > 5 | > 25% | Immediate |
| Medium | 3 - 5 | 10 – 25% | Long-term |
| Tolerable | < 3 | < 10% | No particular measures |

In the best case scenario, based on the German approach (Guideline on Odour in Ambient Air, 2008), annoyance is assessed due to plant odours only. Here, the percentage of "extremely annoyed" persons includes those who classify their level of annoyance on the graphic scale as being above ≥ 7 . Odour limit values were developed on the basis of investigations in which the initial odour impact measured as odour frequency and the degree of annoyance caused to residents assessed by questionnaires were compared. By agreement more than 10% extremely annoyed citizens were defined as critical level where the level of annoyance has to be considered as significant. Based on the results of two dose response studies on odour annoyance due to odour exposure from industrial or agricultural sources (Sucker et al. 2006, 2008) the critical range above that annoyance has to be considered significant is between 4 and 5 on the thermometer scale.

In accordance with the Swiss approach the degree of annoyance in the surveyed residential area can be evaluated as tolerable in almost all survey zones, except for Zone A. In Zone A the degree of annoyance has to be evaluated as medium. Appropriate to the German approach the degree of annoyance in the surveyed residential area can be evaluated as not critical as it is clearly below "5" in all five survey zones.

Moreover, the influence of other environmental stressor (i.e. noise and electromagnetic pollution), and possible non-olfactory factors, e.g. age, education, and length of residence, were tested by means of analysis of covariance. The results showed that the combined effect of exposure due to odour and noise triggers the annoyance reaction, particularly in Zone A. However, residents were not concerned about possible health effects due to electromagnetic pollution. Furthermore, subjects with a problem-focused coping style reacted more sensible to odours in the residential area.

4. Conclusions

In Zone A, annoying odours are perceivable, but according to the Swiss and the German evaluation schemes, odour annoyance level is in an acceptable range.

Concerns relating to possible overestimation of odour annoyance in the residential area were reflected. Overestimation due to confusion with the perception of garbage odours smelling similar to the plant odours was conceivable. Here, the results of the Swiss approach implementing a worst-case scenario showed that in Zone A the degree of annoyance had to be evaluated as medium. In the other survey zones it could be evaluated as tolerable. Overestimation due to knowing the plant is unlikely, as 67 (56%) residents in the survey area and 9 (41%) residents in Zone A did not perceive any odour at all. Only 14 (12%) residents perceive and name the plant odours; of these only 5 (23%) residents were living in Zone A respectively. Here, the results of the German approach implementing a best-case scenario showed that the degree of annoyance could be evaluated as not critical in all five survey zones.

To complete the picture, other environmental stressors, i.e. noise and electromagnetic pollution were taken into account. Particularly in Zone A, a power plant constituted an additional source of annoyance. Residents complained about noise coming from the power lines. As known from other odour annoyance studies, noise pollution triggers the odour annoyance reaction. The combined effect of exposure due to odour and noise causes, that those residents who perceive noise additionally are more sensible to odours. However, residents were not concerned about possible health effects due to electromagnetic pollution.

Furthermore, so-called non-olfactory factors that strengthen or weaken the annoyance reaction independently of the concrete odour exposure level were taken into account. It was shown that residents with the problem-focused coping style react more sensible to odours in the residential area.

As a conclusion, odour abatement measures at the plant will reduce community annoyance reaction only to a small extent. Other annoyance sources like noise pollution have to be tackled too. With regard to the residents, who show a problem-focused coping style, the communication strategy, already started in 2006, may be an effective measure.

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