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Measurements of odour annoyance by integrated assessment methodologies

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This paper describes the methodological approach used for the assessment of odour annoyance employed in a case study carried out in a village in the Province of Modena involving the integration of a number of different techniques. These included the active participation of the local population with the completion of questionnaires combined with the use of sensorial instruments such as electronic noses and staff trained on-site. The methods used, although with inevitable differences, demonstrated a high degree of convergence in the evaluation of the level of annoyance and the temporal distribution of critical periods, identifying odour levels exceeding (although only slightly) the limits to odour emissions laid down by the German legislation taken as the reference threshold (exceeding 10% odour-hours).

1. Introduction

This study had as its goal the investigation of the methods for the measurement of odours at the immission, that is the perception of odours by sensitive receptors. The monitoring activities were carried out in a small town in the Province of Modena where the citizens have complained about the nuisance caused by odours which they claim come from a nearby plant processing slaughter by-products and located about 1500 metres south-south-west from the village.
For this purpose we took into consideration techniques for the evaluation of olfactory annoyance whose use is already well-established in other countries such as Germany and Belgium, based on the judgment of assessors operating directly in the vicinity of the emission source. Reference was made in particular, in this study, to the framework emissions law enacted in Germany (TA Luft, Technical Instructions on Air Quality Control and GIRL - Guideline on odour in ambient air) together with the Technical Guidelines accompanying the above, VDI 3940 and VDI 3883.

2. Materials and Methods

The monitoring undertaken was effected using four investigation methods:

1. Measurement of odour impact by field inspection with trained panellists;
2. Repeated brief Questioning of neighbour panellists;
3. Odour diaries kept by a selected group of residents;
4. Monitoring by means of a sensorial analysis instrument (electronic nose).

2.1 Measurement of odour impact by field inspection with trained panellists

The investigation technique used was that described in the German Guidelines VDI 3940/06 "Measurement of Odour Impact by Field Inspection – Measurement of the Impact Frequency of Recognisable Odours - Grid Measurement".

Following the indications of the above Guidelines, the village was divided into a grid of squares with sides of 150 metres with the points of intersection codified with a letter (A, B, C and D) followed by a progressively increasing number. The theoretical grid was then adapted to the real world village by moving the intersection points when necessary to an accessible point on the ground. The Guidelines indicate that the assessors from the evaluation panel, made up of members selected on the basis of a reference odour (in compliance with the instructions of the EN 13725 regulation) should go to one of the intersection points of the measurement grid on each day of the monitoring period, and fill out a form. The form requires an evaluation to be made every 10 seconds over a period of 10 minutes as to the existence or otherwise of a recognisable odour together with an assessment of its nature (from organic waste = Odour A, from livestock = Odour B, chemical = Odour C, other odour = Odour D, etc.). The assessor must only assess one of the four intersection points of each square on each outing and the Evaluation Panel must be made up of a sufficient number of people to cover the predefined grid. In this case 2 assessors were used who went to five different positions in the grid in order to ensure that each of the 23 squares had one intersection point evaluated each day. Measurements were made twice a week with a total number of 52 outings. The total duration of the investigation covered a period of 7 months in the spring and summer (from March to September). The outings covered the period from 8 o'clock in the morning to 10 o'clock at night. In order to ensure the measurements satisfied representational criteria, an equal number of outings was made for each hour and day in the week excluding Sunday.

2.2 Questionnaire completed twice-weekly by a sample of the resident population

The survey methodology was that described in the German guidelines VDI 3883 "Determination of Annoyance Parameters by Repeated brief questioning of neighbour panellists". This requires a voluntary sample of residents to go outside their homes and record their assessment of the odour perception at pre-set times and days (in our case Wednesdays and Fridays at 8 o'clock in the morning and evening), identifying its intensity (over a scale of 5 levels odours which are not annoying/slightly annoying/annoying/very annoying/extremely annoying) with the completion of a questionnaire accordingly.

2.3 Odour Diaries

A voluntary sample of residents was asked to maintain a diary over the period of the study identifying odour episodes by recording details on a specially designed form writing out the time and place when the episode was identified, its duration, its quality (from organic refuse, from livestock, chemical etc.) and the intensity of the odour causing the nuisance (over the 5-level scale).

The results of these questionnaires were used to confirm the results of the surveys effected using the other methods and to provide information on the distribution throughout the day of the daily "odour episodes".

2.4 Monitoring with sensorial analyser

Over the summer months two sensorial analysers (electronic noses - EN) were installed, one (the CRPA EN) in the centre of the village and the other (the ARPA EN) closer to the plant accused of being the source of the odour annoyance, to obtain a continuous record of any dispersions and its origin. Before the start of the monitoring the company manufacturing the instruments (EOS 385 by Sacmi of Imola) installed "twin" sensors (thin-film M.O.S. sensors) in the EN's. As preparation a "training" stage was also completed using different types of samples taken from emission sources to be found in the area under study. These included "**Plant A**" odours (the plant processing slaughter by-products), "**Plant B"** odours (a biogas plant located to the west of the village), "**livestock farm"** odours and "**neutral air"** in order to make it possible to recognise the olfactory footprints recorded once the continuous monitoring had been completed.

2.5 Accompanying Meteorological measurements

The results deriving from the different techniques set up were then compared with records indicating wind direction available on the basis of the data accessed from the weather centre set up by the local Municipality.

3. Results

3.1 Field inspections: Grid measurements

The analysis of the monitoring forms provided the assessment of the odour hours and the odour load for each assessment square. Using the VDI 3940 method, a particular hour would be considered an **odour hour**, for a particular type of odours, if there is a continuous odour perception for more than 10% of the time, while the odour load for each square was calculated by adding together the odour hours for the four intersection points over the whole period and dividing the resulting figure by the number of measurements (in this case 52). Figure 3.1.1 sets out an example of the calculation of the odour load for one assessment square.

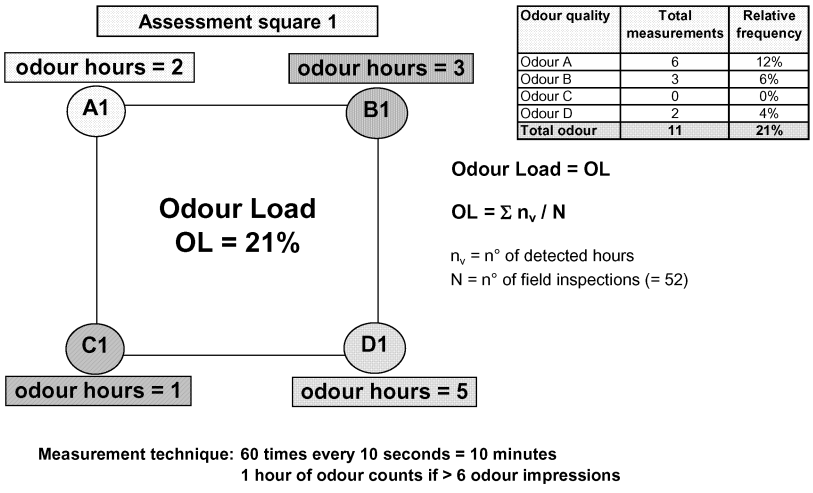

Figure 3.1-1 Example of the calculation of the odour load for one assessment square

The monitoring exercise found that the total odour load averaged out over all assessment squares for the area under study amounted to 44,2% of which 6,6% was of type A (organic refuse), 0.5% for Type B (livestock farm), 5.1% for Type C (other production activities) and 32,0% for Type D (other odour). According to the German guidelines on odours the maximum frequency of odours, this being understood to mean the relative frequency of times when odours are clearly perceptible, must not exceed the limit of 10% for residential areas otherwise the annoyance caused by the odours is considered to be significant. The odour loads established are thus under the limit with the exception of the "other odour" category which includes a wide variety of odours including at times, pleasant ones.

3.2 Twice-weekly questionnaire completed by a sample of the local residents

The twice-weekly questionnaires were processed in compliance with the suggestions made by the German guidelines (VDI 3833) for calculating an olfactory annoyance index, calculated as an average of positive reports and weighted on the annoyance category attributed by the people making the record.

The results of the processing effected have been set out in Figure3.2-1

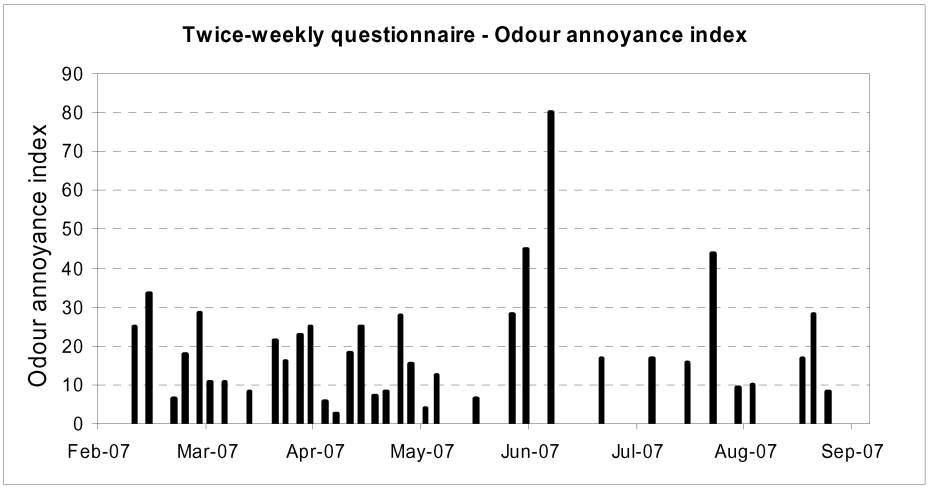

Figure 3.2-1 Olfactory Annoyance Index established on the basis of twice-weekly questionnaires

3.3 Odour Diaries

In analogy with the procedure used for the twice-weekly questionnaires, an Olfactory Annoyance Index was also determined using this technique. In the processing however, it was necessary to take account, in addition to the categories of nuisance, of the following factors: the duration, the number of active assessors (taking account of the dates on which each assessor started and ended his or her participation in the monitoring) and the odour types. The total number of reports obtained during the monitoring amounted to 1200 (of variable duration and annoyance level). Of these, 93%

were attributed to Odour A (organic refuse), that is what residents recognise as coming from the plant under accusation as the cause of the nuisance). The processing, effected on time intervals of 5 minutes, was thus limited to reports relating to Odour A. An Annoyance Index was calculated taking account of two weighting factors – degree of annoyance and persistence over time. Figure 3.3-1 and Figure 3.3-2 set out two summarising graphs, identifying the average week and average day respectively based on the whole monitoring period.

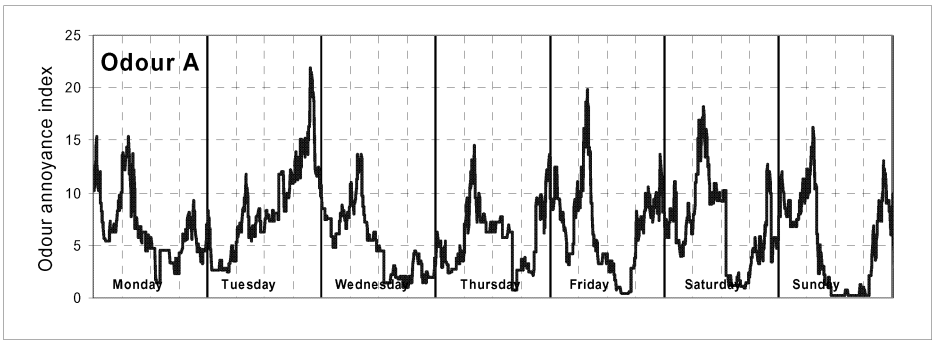

Figure 3.3-1 Odour Annoyance Index obtained from the Odour Diaries – Average Week

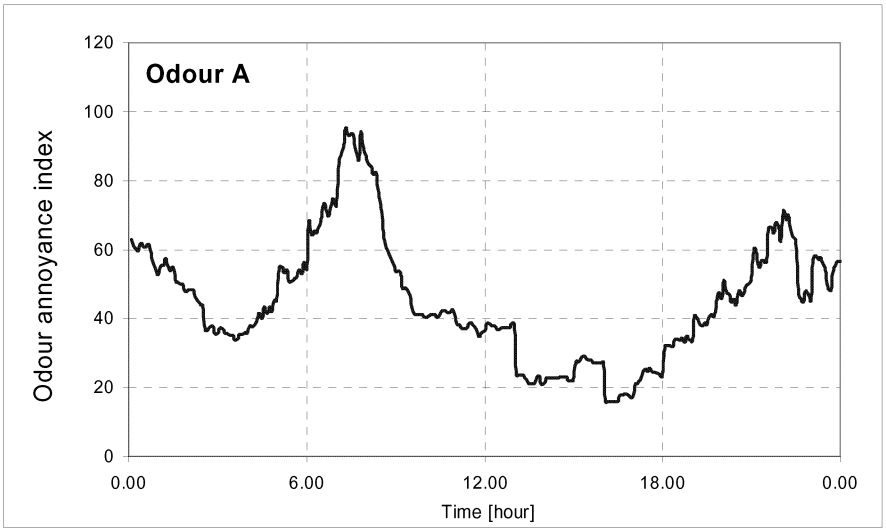

Figure 3.3-2 Odour Annoyance Index obtained from the Odour Diaries – Average Day

Looking at the resulting figures it is clear that the day with the highest degree of annoyance is Tuesday, the day on which the plant restarts its working activities. The times during the day registering the highest peaks in the Annoyance Index are between

6 and 8 o'clock in the morning and 10 and 12 o'clock at night. This can be explained by analysis of the average daily wind directions – the direction of winds over the night-time up to 6 o'clock in the morning tends to be from the south, that is, consistent with the position of the organic waste processing plant in relation to the village (it is located to the south-south-west of the village). The wind then tends to change to blowing from the west, then to the north and east, returning to the south at about 10 o'clock p.m. This trend tends to corroborate the plant's responsibility on the basis of the reports by the residents.

In the same way as for the field inspection, odour hours were calculated from the odour diary data. An "odour hour" was defined as an hour when an odour was reported over more than 10% of that hour. The calculation results indicated relative frequency of odour hours 29% over the whole monitoring period. Reports were however only considered plausible when the wind direction was within an angle of +/- 60° with respect to the direction of the plant in relation to the village(in analogy with the suggestions made in VDI 3940 as a plausibility criterion), with the odour-hour percentage reducing to 13.4% as a consequence.

3.4 Monitoring with sensorial analysers

The data collected over the continuous monitoring stage represented the "match set" of measurements which had to be compared with the labels given to the measurements made during training – the "training set". This matching process was carried out for each day of the monitoring period based on the R/R_0 feature.

The data analysis was effected by means of the recognition algorithm K-NN of the Nose Pattern Classifier (NPC) software of the Electronic Nose EOS 835.

Table 3.4-1 provides a monthly summary of the recognition data from the two sensorial analysers for each odour category on which the training stage was based: neutral air (environmental background), Plant A, Plant B and the livestock farm.

Table 3.4-1 Number of recognitions effected by the sensorial analysers and their percentage division over the different odour categories

Measurement Period	Environment (Neutral Air)		Plant A		Plant B		Livestock		Total	
CRPA-EN										
June	3126	88.9%	387	11.0%	2	0.1%	3	0.1%	3518	100%
July	6473	90.4%	681	9.5%	2	0.0%	3	0.0%	7159	100%
August	6690	90.1%	734	9.9%	1	0.0%	4	0.1%	7429	100%
September	6140	85.4%	1032	14.4%	12	0.2%	3	0.0%	7187	100%
Total period	**22429**	**88.7%**	**2834**	**11.2%**	**17**	**0.1%**	**13**	**0.1%**	**25293**	100%
ARPA-EN										
June	4011	87.2%	587	12.8%	0	0.0%	4	0.1%	4602	100%
July	6341	89.6%	733	10.4%	0	0.0%	1	0.0%	7075	100%
August	6724	90.5%	701	9.4%	0	0.0%	4	0.1%	7429	100%
September	4159	80.1%	1028	19.8%	0	0.0%	4	0.1%	5191	100%
Total period	**21235**	**87.4%**	**3049**	**12.5%**	**0**	**0.0%**	**13**	**0.1%**	**24297**	100%

The percentage recognition of the odour coming from Plant A (that accused of olfactory annoyance) amounted to 11.2% in the case of the CRPA Electronic Nose and 12.5% in the case of the ARPA Electronic Nose. The recognition percentage for the two other types of odours (plant B and the livestock farm) were virtually non-existent. If the results from the two instruments are compared, it can be seen that there are a number of points when their measurements of the Plant A odour coincide, the recognition of the odour tends to be concentrated over the night-time, early morning, late afternoon and the evening for both instruments.
An annoyance Index was drawn up on the basis of the Electronic Nose data as well, in the form of the average hourly recognition of the waste processing plant odour effected over the whole period. Comparison between the average annoyance index based on records produced by residents and that obtained from the data produced by the two Electronic Noses shows very close correspondence in the critical times, early morning and late evening.

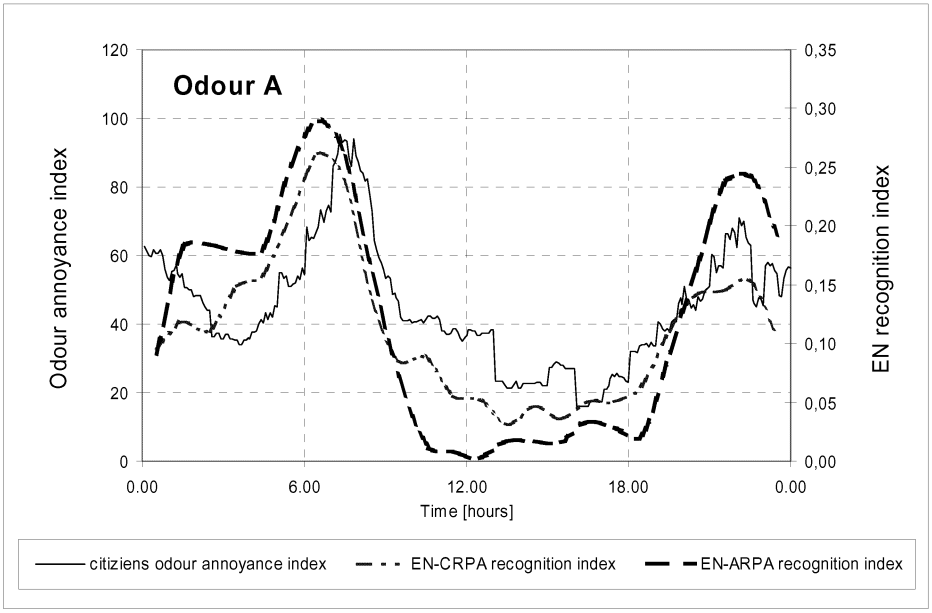

Figure 3.4-1 – Annoyance Index Average Day based on Plant A odours identified by the two Sensorial Analysers

4. Conclusions

The possibility of integrating different methodological approaches to the assessment of odours in relation to emissions makes it possible to check and evaluate the results obtained. The comparison of the results obtained from the different techniques used during the monitoring period highlighted a number of points of correspondence.
There is a correlation between the annoyance index obtained from the odour diaries and wind direction, thus those times when the largest number of reports of odours (high

index) are almost exclusively when the wind is coming from the direction of the plant A (south-south-west).
The comparison between the average monthly annoyance indices obtained from the two types of survey effected through a questionnaire indicates an increase in the olfactory annoyance during June.
A comparison of the Plant A odour trends as indicated by the average annoyance index from the diary data on the one hand, and by the daily measurements effected by the two sensorial analysers on the other, reveals close correspondence in the identification of early morning and around 10 in the evening as the periods during the day with the greatest presence of the odours concerned.
If the calculation of the odour hour frequency from the diary data is restricted to data covering the time from 8 a.m. to 10 p.m. (the period of time during which the *field inspections* were carried out), the value of 13.4% calculated over 24 hours reduces to 5.6%, extremely close to the 6.6% identified with the field inspections. This leads to the conclusion that odour-hour percentage calculated on the basis of the diary data represents a reliable estimate of what the results of the *field inspections* would have been if effected over a 24 hour period. On this basis, it can be concluded that the situation under consideration does represent olfactory annoyance because it is in excess of the odour-hour percentage of 10% set by the German regulations.
This result is also confirmed by the processing of the continuous monitoring data obtained from the sensorial analysers for which the recognition percentage of the Plant A odour amounted to 11.2% in the case of the CRPA electronic nose and 12.5% for the ARPA instrument.

3. References

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VDI 3883/93 Effects and assessment of odours – Determination of annoyance parameters by questioning – Repeated brief questioning of neighbour panellists.

VDI 3940/06 “Measurement of odour impact by field inspection – Measurement of the impact frequency of recognizable odours – Grid measurement”.

4. Acknowledgements

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