

DIRECTIVE ON ODOUR IN AMBIENT AIR – AN ESTABLISHED SYSTEM OF ODOUR MEASUREMENT AND ODOUR REGULATION IN GERMANY

Ralf Both*

**North Rhine-Westphalia State Environment Agency, Wallneyer Str. 6, 45133 Essen, Germany*

ABSTRACT

The legal basis for any requirement with respect to ambient air quality is the German Federal Protection Act for Ambient Air. According to § 3 Federal Protection Act all odours caused by plants are defined as an annoyance. The problem is to find out whether an annoyance has to be considered as a significant disturbance. In the Directive on Odour in ambient air a complete system is designed, beginning with measurement methods and concluding with ambient air quality requirements. In the following paper the tenor of the Directive on Odour is shortly presented, some main aspects of more than five years of practical experience will be shown and a perspective on some future investigations and developments will be given. As a conclusion it is pointed out that in practice the Directive on Odours has been successful. Both methods, field measurements with panels and dispersion modelling, are generally qualified for the determination of odour loads. The restriction of odour loads by limit values expressed as odour frequency per year for certain areas has been established in a lot of cases.

KEYWORDS

Annoyance; field measurements; limit values; odour; odour frequency; odour load

THE NEED OF ODOUR REGULATION IN GERMANY

The legal basis for any requirement with respect to ambient air quality is the German Federal Protection Act for Ambient Air (1974/1990) and the Technical Instruction on Air Quality Control (1986). According to § 3 Federal Protection Act for Ambient Air odours caused by plants are treated as an annoyance. The problem is to find out whether an annoyance has to be considered as significant (relevance of the annoyance).

If odour emissions from plants occur this question has been answered in every licensing or surveillance procedure. In cases of urban development planning evaluations of odours in ambient air are also required.

Odour emissions are relevant air pollutants in a lot of industries. Table 1 provides an overview that shows in which branches of industry odour questions are relevant. This register is based on written experts opinions proven by the State Environment Agency as an inspection authority for North Rhine-Westphalia. These validity checks guarantee a standardised determination and evaluation of odour all over the state. Between 1995 and 1999 altogether approx. 250 validity checks were carried out. This is equivalent to perhaps 40 – 60 cases per year.

Most written experts opinions deal with odours from livestock farming (59 cases), followed by composting plants including fermentation processing (27) and waste water treatment plants including sludge composting (19). Another main focus is waste management (14) and food and

feeding stuff production (11). On the other hand "classical" industrial plants are rather seldom (paint finishing plants 9, chemical industry 6). As a conclusion it can be pointed out that in practice the greatest number of cases is caused by biogenic sources.

Table 1. Relevant odour emitting industries in North Rhine-Westphalia.
Data based on written experts opinions be proven by the State Environment Agency between 1995-1999.

Odour emitting industry	Number of cases
Livestock farming	59
Composting plants incl. fermentation processing (3)	27
Waste water treatment plants incl. sludge composting (2)	19
Waste management - waste sites (3), waste treatment (5), waste utilisation (3), mechanical-biological treatment of waste (1), soil regeneration (1), waste incineration (1)	14
Utilisation of agriculture products	
Food production (5), feeding stuff production (3), grease recovery (2), tannery (1)	11
Paint finishing plants	9
Chemical industry incl. bitumen production (2)	6
Metal processing	6
Foundries	6
Textile finishing	6
Chipboard industry	5
Brickwork	3
Different plants (each only one individual case): Paper production, brake pad production, engineering industry, air port, abrasives industry, plastics processing, vulcanisation, petrol station, printing, glass wool production, circuit board production	11
Other inquiries:	
Complaints, local authorities, strategy of odour measurement and evaluation etc.	~70

The number of written experts opinions all over North Rhine-Westphalia is much greater. A feedback concerning the experience of licensing and surveillance authorities in summer 2000 shows that approx. 5000 cases during the last five years have been evaluated. The amount of cases in Germany is a multiple of this.

In nearly all these cases the odour regulation instrument was the Directive on Odour in ambient air (1994, revised version 1999). In this directive, a complete system is designed, beginning with measurement methods of the existing odour load and calculation of the expected odour load and concluding with ambient air quality requirements expressed as limit values in terms of maximum permitted odour frequency in ambient air in certain areas (Both, 1996).

In this paper first the tenor of the Directive on Odour is shortly presented, second some main aspects of more than five years of successful practical experience will be shown and at last a perspective on some future investigations and developments will be given.

THE DIRECTIVE ON ODOUR IN AMBIENT AIR – AN ESTABLISHED AND PROVED SYSTEM OF ODOUR MEASUREMENT AND ODOUR REGULATION

The System of data acquisition, analysis and evaluation

The main objective of the odour measurements mentioned in the Directive on Odour are recognisable odours occurring in a certain area. A distinct difference is made between ubiquitous odours like traffic exhausts or smelling vegetation on the one hand and recognisable and distinguishable odours caused by plants on the other hand. Since more than ten years the relevant parameter for odour assessment has been the amount of time per year in which odour occurs (odour frequency = ambient odour characteristic) (VDI 1990).

There are two basic methods given in the Directive on Odour for determining odour frequency in ambient air: first, field measurements with panels and second, dispersion modelling.

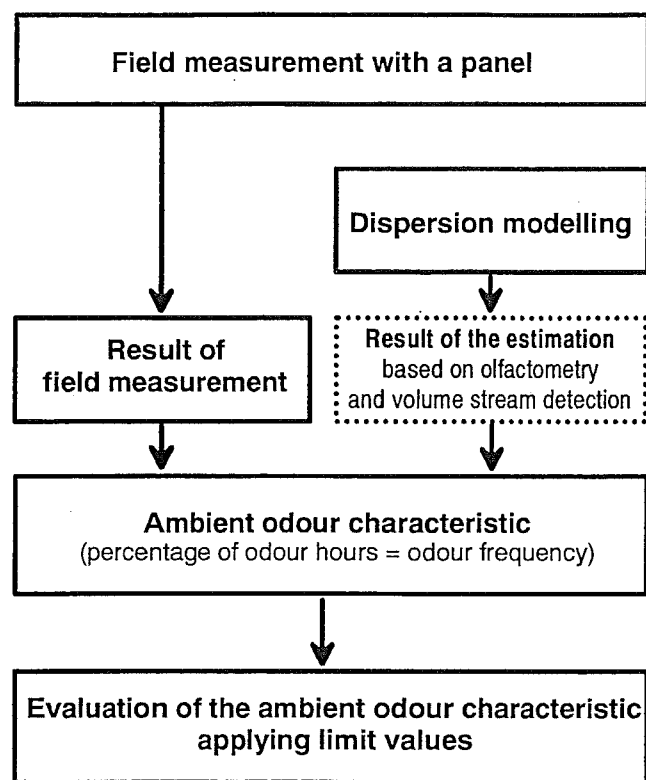
Dispersion modelling includes olfactometric emission measurements, volume stream determination and / or detection, and determination of meteorological conditions. The objective is to calculate recognisable odours expressed as odour frequency per year for certain areas. It depends on the dispersion model and the associated parameters how accurate the results are in line with the real conditions on site. The typical field of application of dispersion modelling is the estimation of odour frequencies probably caused by plants to be built (ambient odour characteristic of the expected load). If the odour emission rate is known, it is also applied for estimating the ambient odour characteristic of existing plants (existing load). But in any case, results of dispersion modelling are only an estimation.

Contrary to this, the objective of field measurements carried out by panels is to record odours that are immediately recognisable under real field conditions. The odour in ambient air is determined by systematic field measurements using trained and selected panel members (Guideline VDI 3940, 1993). Thus the result of field measurements directly depends on the odour load (existing load) in a certain area expressed as odour frequency and represents what residents would perceive. These measurements are definitely more advantageous than other methods if for example there are more than one existing emission source and / or fugitive sources, causing perhaps a lot of complaints. Also, if the frequency distribution of dispersion categories for the location isn't available field measurements are advantageous.

In Figure 1, an overview of the system of data acquisition, analysis and evaluation is given based on the Directive on Odour. The result of these methods is the ambient odour characteristic. In the case of dispersion modelling, it is an estimated value, in the case of the field odour measurements it is a result of an immediate and precise recording. In any field of application, the result of field measurements carried out by panels is always the main objective \Rightarrow the target value for all other methods. The overriding importance of the method of field measurements with panels is presented in Figure 1 where this method is placed above the method of dispersion modelling. Herein it is assumed that the result of field measurements on site is as representative as possible for the existing conditions.

The integration of the evaluation criteria in Figure 1 points out the close relationship between the two different measurement methods, their results and the ambient odour characteristics on the one hand and the evaluation procedure and the limit values on the other hand. As established in the Directive on Odour the limit values are only to be applied in connection with the methods mentioned. This particular procedure requires all other approaches to present proof of reproducibility.

Figure 1. System of data acquisition, analysis and evaluation based on the Directive on Odour



However, field measurements are not as common as dispersion modelling as table 2 shows. The reason for this is the duration of half a year for field measurements. Also, sometimes, cost aspects are a further reason. Depending on the size of the assessment area costs for field measurements vary between 18.000 and 25.000 German Marks (14.400 – 20.000 AU\$).

Table 2. Methods in use to determine odour load in ambient air in Germany

Used method	Percentage of appliance
Dispersion modelling	approx. 75%
Field measurements with panels	approx. 15%
Simplifying methods	approx. 10%

Odour limit values

In the Directive on Odour ambient air quality requirements are fixed as limit values as given in Table 3. These values limit the amount of recognisable odour related to plants. A difference is made between two types of areas, residential or mixed areas on the one hand and trade or industrial zones on the other hand. Other areas, where persons do not only stay temporarily as well, could be assigned to columns 1 or 2 in Table 3 or to intermediate values.

These limit values were developed on the basis of investigations (Steinheider et al. 1994, 1998) in which the existing odour load measured as odour frequency (Guideline VDI 3940, 1997) and the degree of odour annoyance of residents assessed by questionnaires according to guideline VDI 3883 Part 1 (1997) were correlated. As a result odour frequencies between 10% and 20% were found to

be the critical range where a significant annoyance according to the definition of the German Federal Protection Act for Ambient Air is recognised. Per convention the limit values were fixed as shown in table 3. More details on determination of annoyance will be given by Sucker et al. "Adverse effects of environmental odours: annoyance response and symptom reporting" in these proceedings.

Table 3. Limit values for odour in ambient air in different areas.

Residential, mixed area		Trade, industrial zones	
relative frequency	%	relative frequency	%
0.10	10	0.15	15

Furthermore there exists a so called "irrelevance criteria" in licensing. If the expected load of the plant evaluated does not exceed the value 0.02 (= 2 %) in areas where persons do not only stay temporarily the licensing of the plant shall not be denied. The "irrelevance criteria" provides the considerable advantage that independent of the situation on site no further investigations are required. This means that even if there is a certain existing odour load the building of a new plant can be licensed as long as it's expected ambient odour characteristic does not exceed the value 0.02.

EXPERIENCE FROM OVER FIVE YEARS OF REGULATION WITH THE DIRECTIVE ON ODOUR

Odour limit values – reasonable modifications

After a feedback period of appliance of the Directive on Odour in practice, in some individual cases it was required to adapt the limit values for special conditions. In the following cases modifications of these limits seem to be plausible.

- Employees of a neighbouring plant are regarded as being neighbours like residents and, according to the German Federal Protection Act for Ambient Air, they have to be protected against a significant annoyance by odours. But due to a reduced time of presence in comparison to residents the limit values could be raised.
- In health-resorts the existing odour load in ambient air should not exceed 10 %. But it could be reduced if, for example, there are special local requirements on air quality.
- Camping sites need not to be protected more than surrounding areas.
- Holiday resorts with cottages or flats are classified as residential areas.
- Allotment garden areas are classified as industrial areas.
- In the case of seasonal odour sources like sugar campaign it is necessary to work out an individual assessment with a special focus on local conditions.
- For livestock farming special regulations exist. In Germany there are several guidelines available (VDI 3471, 1986, VDI 3472, 1986) which define the legal distance between a farm and the next dwelling house in form of a simple circle. The radius of the circle depends on the number of animals and some technical parameters. When the distance between farm and next dwelling house is less than the setback distance a written expert opinion is required based on the Directive on Odour. Then the odour frequency is normally calculated by a consultant by dispersion modelling. But in the case of livestock farming different limit values are in use as shown in table 4.

The legal reason for this modification is that livestock farming is privileged in outskirts or rural areas in Germany. Furthermore the odour of livestock farms is declared as locally usual in these areas. But nevertheless these odours cause an increasing number of complaints due to the fact that acceptance in population is decreasing.

Table 4: Limit values for odour in ambient air in the case of livestock farming.

Residential, mixed area		Villages with livestock farming		Outskirts and rural areas	
relative frequency	%	relative frequency	%	relative frequency	%
0.10	10	0.15	15	0.15 - 0.20	15 - 20

Odour intensity and hedonic tone

Odour intensity and hedonic tone are parameters that are known in the research of odour effects. From a scientific point of view it is interesting to investigate these effects. But until now, in Germany there are only few cases in which odour intensity or hedonic tone had to be taken into account.

In one case very weak odours caused by a plant occurred. The licensing authority decided to raise the limit value for very weak odours. In other cases very strong odours could be perceived only as peaks but the odour frequency in ambient air didn't exceed the limit values. In these cases the surveillance authority decided that the odour intensity of the peak had to be lowered by emission abatement.

These selected practical experiences are verified by results obtained out of the investigations mentioned in connection with the development of limit values (Steinheider et al. 1994, 1998). Increasing odour intensities did not necessarily lead to an increasing degree of annoyance. It was sufficient for the description of the odour situation on site to determine recognisable odours expressed as odour frequencies (Steinheider, Winneke 1992). Additionally, the determination of odour intensities in field measurements cause some methodological problems.

The hedonic tone of odour in terms of pleasant and unpleasant generally didn't appear as a relevant parameter for the evaluation procedure. The assumption that all ambient odours can cause a relevant annoyance, is also valid for pleasant odours if for example they cover longer periods. Hedonic tone in practice is only a problem if unpleasant odours are emitted. In these cases, no matter what limitations require, there is the need to avoid perceiving these odours in residential areas. Otherwise a lot of complaints and public attention will occur. Therefore there is no need for a special regulation which would only mean the drawback of a much more complicated system including some methodological problems.

In the case of the hedonic tone there is one important exception. If nausea and sickness causing odours are detected in ambient air, a reaction of the authority responsible is required immediately (Steinheider et al. 1993). According to the Federal Protection Act for Ambient Air such odours have to be treated not as an annoyance but as a health risk.

The points described above are mainly drawn out of experience. There are a few hints in literature that odour intensity and hedonic tone play a role in odour annoyance. But by now there are no standardised methods to measure these parameters in ambient air in residential areas where they may cause complaints. Also there is no elaborated system which could be used for regulation. Therefore the North Rhine-Westphalian and Baden-Württembergian Ministries of the Environment have assigned a scientific investigation in 1999. The objectives of this project are:

- to develop methods to measure odour intensity and hedonic tone by panels in ambient air,
- to investigate interaction between odour frequency, odour intensity and hedonic tone,
- to determine odour annoyance with a special questionnaire according to guideline VDI 3883 Part 1 (1997) and finally
- to find out if statistically significant correlation probably assessed is strong enough to modify the proved system of the Directive on Odour in ambient air.

The paper "Adverse effects of environmental odours: annoyance response and symptom reporting" presented by Sucker et al. in these proceedings outlines the background of this project particularly with regard to the relationship between odour load and odour annoyance in more detail.

STANDARDISATION OF ODOUR MEASUREMENTS AND HARMONISATION OF REPORT STRUCTURE

Additionally, a very important effect of the Directive on Odour in ambient air is the harmonisation of report structure and the standardisation of odour measurements.

Since the Directive on Odour has been in use any consultant knows what parts have to be in a written expert opinion and how to describe expected and existing odour load in residential areas. In comparison to former times the reports are much more comprehensible to a third party. And in addition the authorities responsible now have a guideline how to assess odour loads. Altogether this leads to an extensively harmonised treatment of residents and plant operators all over Germany.

In the field of odour measurement the Directive of Odour was the first guideline in Germany in which quality requirements for both olfactometry and odour panel members were fixed. In table 5 the requirements for panel members are listed. If the tested person doesn't fulfil the criteria it could not be used as a panel member neither for olfactometry nor for field measurements. Because of these requirements the quality of odour measurements has increased distinctly during the last years.

Table 5. Quality requirements for panel members

Odourant	Lower limit [$\mu\text{g m}^{-3}$]	Odour threshold [$\mu\text{g m}^{-3}$]	Upper limit [$\mu\text{g m}^{-3}$]
n-butanol	60	123	250
Hydrogen sulfid	0.7	1.4	2.8

According to §§ 26, 28 Federal Protection Act for Ambient Air there are procedures which give the authorities responsible the opportunity of proving whether measuring institutes fulfil the quality criteria. When the proposed CEN standard prEN 13725 (1999) will be accepted some of these criteria will be replaced. In table 6 the number of measuring institutes in Germany is listed which pass the procedure in accordance to §§ 26, 28 Federal Protection Act for Ambient Air.

Table 6. Number of measuring institutes in Germany is listed which pass the procedure in accordance to §§ 26, 28 Federal Protection Act for Ambient Air

Federal State	Emission measurement only	Emission and ambient air measurement
Baden-Württemberg	7	6
Bavaria	8	7
Berlin	2	2
Brandenburg	-	-
Bremen	1	1
Hamburg	2	2
Hesse	3	3
Mecklenburg-Western Pomerania	3	2
Lower Saxony	4	4
North Rhine-Westphalia	10	9
Rhineland-Palatinate	5	5
Saarland	1	1
Saxony	6	6
Saxony-Anhalt	-	-
Schleswig-Holstein	1	1
Thuringia	1	1
Germany	54	50

CONCLUSIONS AND FUTURE DEVELOPMENT

The practical experience from more than five years operating with the Directive on Odours has been successful. Both methods, field measurements with panels and dispersion modelling, are generally qualified for the determination of odour loads. The restriction of odour loads by limit values expressed as odour frequency per year for certain areas has been established to assess odour annoyance in a lot of cases. It has been shown that in some individual cases it is possible to adapt these values for special conditions. Also, the quality of odour measurements and reports are enhanced by the Directive on Odour. Among other procedures future developments will focus on dispersion modelling and ring tests for olfactometry.

Dispersion modelling of odours. At present in Germany a special dispersion model for odours is being developed. Its aim is to cope with the fact that odours are perceived in short time intervals and cannot be described with one hour mean values. Also the recognition of odours in ambient air compared to lab conditions still is a point of interest.

Ring tests for olfactometry. Besides the performance of field investigations like the hedonic project, another field of activity will be the organisation of ring tests for olfactometry in the next years. It is planned to invite measuring institutes to participate in ring tests and to check if their measuring method is precise enough to fulfil the quality requirements of the Directive on Odour and / or the CEN-guideline on olfactometry.

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