Odor Regulations in Germany - A New Directive on Odor in Ambient Air

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ABSTRACT

In Germany, the odor situation on site can be characterized as a realm between odor sources and residential areas. This situation influences the licensing procedures for new plants and the surveillance procedures in the vicinity of existing plants in Germany. In many cases, administration bureaus require an expertise about the existing odor load caused by plants already working and the expected odor load of the projected plant.

Therefore, a standardization of measurement methods, evaluation and regulation procedures is necessary. To ensure that coherent standards and evaluation methods are used in licensing and surveillance practice, a "directive on odor in ambient air" has been developed in North Rhine-Westphalia.

The paper presented explains the complete system designed in the "directive on odor". It begins with measurement methods of the existing odor load, the calculation of the expected odor load and concludes with ambient air quality requirements expressed as limit values in terms of maximum permitted amount of odor (odor frequency per year) in certain areas. To illustrate the odor assessment and regulation practice according to the "directive on odor" results of field measurements in the vicinity of a pig farm are presented as an example. Finally, these results together with some considerable experiences out of more than two years of application of the "directive on odor" are discussed.

INTRODUCTION

General Remarks

In Germany, the odor situation on site can be characterized as a realm between odor sources and residential areas. The distance between residential areas and for example industrial plants is usually smaller than 1000 m. Therefore in some areas, there are a lot of complaints about odor annoyances. This situation influences the licensing procedures for new plants and the surveillance procedures in the vicinity of existing plants in Germany. In many cases, administration bureaus require an expertise about the existing odor load caused by plants already working and the expected odor load of the projected plant.

Acts and Regulations

The legal basis for any requirement with respect to ambient air quality is the Federal Immission Control Act (Federal Protection Act for Ambient Air, BImSchG: Bundes-Immissionsschutzgesetz) [1] and the Technical Instruction on Air Quality Control (Technical Instruction for the Prevention of Air Pollution, TA Luft: Technische Anleitung zur Reinhaltung der Luft) [2]. According to § 3 the BImSchG all odors caused by plants are an annoyance. The problem is to find out whether annoyances can be considered disturbing significant (relevance of the annoyance). But neither the BImSchG nor the TA Luft give any guidelines for a decision about what constitutes an annoyance. In a first step, an outline from 1986 presented limits of the allowable amount of odor. The relevant parameter was and still is the amount of time per year spent with odor (odor frequency = ambient odor characteristic). But there was nothing said about the method of how to measure the odor frequency. This gap is closed by a new administrative regulation. The "Directive on Odor in Ambient Air" [3]. In this directive, a complete system is designed, beginning with measurement methods of the existing odor load, the calculation of the expected odor load and concluding with ambient air quality requirements expressed as limit values in terms of maximum permitted odor frequency in ambient air in certain areas.
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frequency in ambient air in certain areas.
Objective of Odor Measurements

The main objective of the odor measurements mentioned in the "directive on odor" are recognisable odors on site. A distinct difference is made between ubiquitous odors like traffic exhausts or smelling vegetation on the one hand and recognisable and distinguishable odors caused by plants on the other hand. To make this distinction it is necessary to establish a certain odor quality code for each measuring program with a short and precise description of the possible odors. Furthermore the panel members have to be trained on site.

The System of Data Acquisition and Analysis

There are two basic methods given in the "directive on odor" for determining odor frequency in ambient air: first, field measurements with panels and second, dispersion modeling.

Dispersion modeling includes olfactometric measurements, volume stream determination and/or detection, and meteorological conditions. The objective is to calculate recognisable odors expressed as odor 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 modeling is the estimation of odor frequencies probably caused by plants to be built (ambient odor characteristic of the expected load). If the odor emission rate is known, it is also applied for estimating the ambient odor characteristic of existing plants (existing load). But in any case, the results of dispersion modeling are nothing more than an estimation.

Contrary to this, the objective of field measurements carried out by panels is to record odors which are immediately recognisable under true conditions. Thus the result of field measurements is directly dependent on the odor load (existing load) in a certain area. These measurements are definitely advantageous to other methods if there is for example more than one existing emission source, causing perhaps a lot of complaints.

In Figure 1, an overview of the system of data acquisition and analysis based on the "directive on odor" is given. The result of these methods is the ambient odor characteristic. In the case of dispersion modeling, it is an estimated value, in the case of the field odor 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 - - 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 modeling. Herein it is assumed that the result of field measurements recorded on site is as representative as possible for the existing conditions.

The integration of the evaluation criteria in Figure 1 points out the distinct connection between the two different measurement methods, their results and the ambient odor characteristics on the one hand and the evaluation procedure and the limit values on the other hand. As established in the "directive on odor" 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.

THE LEGAL FRAMEWORK OF THE "DIRECTIVE ON ODOR"

Ambient Air Quality Requirements - Limit Values

Prior to the evaluation of the odor loads licensing and surveillance authorities have to verify if the state of the art in emission reduction is in use as well as whether the stack height meets the requirements of the "directive on odor". The minimum stack height has to guarantee that the ambient odor characteristic for the expected load does not exceed a value of 0,06 (6 %) in the assessment area (All the frequency values in the "directive on odor" are expressed as relative frequencies. They can be transformed to percentages by multiplying by 100 as shown in Table 1 to make them more descriptive.). After this verification the evaluation of the odor load is carried out.

In the "directive on odor" ambient air quality requirements are fixed as limit values as given in Table 1. These values limit the amount of recognisable odor 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, in which persons also do not only stay temporarily, must be assigned to columns 1 or 2 in Table 1.
Furthermore there exists a so called "irrelevance criteria" in licensing. If the expected load of the plant to be evaluated does not exceed the value 0.02 (= 2 %) in assessment squares 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 from the situation on site no further investigations are required. Which means that even if there is a certain existing odor load the building of a new plant can be licensed as long as it's expected ambient odor characteristic does not exceed the value 0.02.

**Determination of the Existing, the Expected and the Total Load**

There are three different parameters which have to be determined according to the evaluation procedure of the "directive on odor":
- the ambient odor characteristic of the existing load \( (\text{AOC}_{\text{EXI}}) \),
- the ambient odor characteristic of the expected load \( (\text{AOC}_{\text{EXP}}) \) and
- the ambient odor characteristic of the total load \( (\text{AOC}_{\text{TOT}}) \).

\( \text{AOC}_{\text{EXI}} \): The ambient odor characteristic of the existing load \( (\text{AOC}_{\text{EXI}}) \) is calculated by using Equation (1).

\[
\text{AOC}_{\text{EXI}} = c \times n_{\text{EXI}} \times N^{-1}
\]

where
- \( n_{\text{EXI}} \) = number of positive records ("odor hours")
- \( N \) = total number of records per assessment square (52 or 104) during the assessment period
- \( c \) = correction factor

\( N, n_\text{v} \), and the term "odor hours" are immediately related to the method of field measurements. To make these variables more transparent they are explained in detail in the next section.

The correction factor \( c \) (see Table 2) considers the varying degree of accuracy of the existing load determined by field measurements in relationship to the total number of records per assessment square being either 52 or 104. The calculation of the correction factor \( c \) is based on a hypothesis examination using binomial distribution and a (statistical) uncertainty of 20 %. For further details see [4] and [5].

\( \text{AOC}_{\text{EXP}} \): The ambient odor characteristic of the expected load \( (\text{AOC}_{\text{EXP}}) \) is calculated by using Equation (2).

\[
\text{AOC}_{\text{EXP}} = n_{\text{EXP}} \times 9^{-1} \times 8760^{-1}
\]

where
- \( n_{\text{EXP}} \) = number of "odor hours"
- \( 9 \) = number of points per assessment square in dispersion modeling
- \( 8760 \) = hours of a year

The dispersion models in use are based on the Gaussian distribution according to the distribution model listed in the TA Luft. All these models calculate odorant concentrations per point and hour. For the determination of "odor hours" (odor frequencies) they need special accommodations. These accommodations have to ensure that, on the basis of an odorant flow rate expressed in odor units per hour [6], recognisable odors are calculated. Furthermore short time odorant concentration peaks which are detectable in ambient air have to be taken into account.

\( \text{AOC}_{\text{TOT}} \): The ambient odor characteristic of the total load \( (\text{AOC}_{\text{TOT}}) \) is calculated by using Equation (3).

\[
\text{AOC}_{\text{TOT}} = \text{AOC}_{\text{EXI}} + \text{AOC}_{\text{EXP}}
\]

where
- \( \text{AOC}_{\text{EXI}} \) = ambient odor characteristic of the existing load
- \( \text{AOC}_{\text{EXP}} \) = ambient odor characteristic of the expected load

Summing up odors in this form is a convention simplifying the conditions in reality. But it allows to apply the "directive on odor" even in complicated cases. Many case studies need to be conducted, but, up until now no other practicable method offering comparable advantages seems to be a perfect solution.
Relevance of the Annoyance
The odors in ambient air are considered as a relevant annoyance if the total load exceeds the limit values given in Table 1. The licensing and surveillance authorities are responsible for this evaluation procedure. As a rule, their decision is based on an expertise on the odor frequencies in ambient air in the vicinity of the respective plant.

For these evaluation procedure the odor intensity on site is generally irrelevant. While drafting the "directive on odor" some investigations were carried out relating the odor load and the degree of annoyance in residential areas. Selected results showed that increasing odor intensities did not necessarily lead to an increasing degree of annoyance. It was sufficient for the description of the odor situation on site to determine recognisable odors expressed as odor frequencies [7]. Additionally, the determination of odor intensities in field measurements causes some methodological problems.

The hedonic tone of odor in terms of pleasant and unpleasant is also irrelevant for the evaluation procedure. The assumption that all ambient odors can cause a relevant annoyance, is also valid for pleasant odors if they cover for example longer periods. In the case of the hedonic tone there is one important exception. If nausea and sickness causing odors are detected in ambient air, a reaction of the authority responsible is required immediately [8]. According to the BImSchG these odors have to be treated not as an annoyance but as a health risk.

ODOR MEASUREMENTS IN THE VICINITY OF A PIG FARM
Some of the main points of application of the "directive on odor" as described above will be explained in detail in the following section. By the example of a pig farm general requirements are opposed to the specific adjustment to a particular case.

The Situation on Site
In the vicinity of a livestock farm with approximately 4000 pigs, people complained about strong odors caused by the pig sty (not by the spreading of manure). The distance to the neighborhood was about 750 m to 1500 m (see Figure 2). A multitude of complaints had been listed over a period of approximately 10 years. They culminated in an official registration of the complaints and the reaction of the local authorities thereafter. Due to this public pressure, the licensing and surveillance authority responsible (NRW State Environment Bureau) commissioned the NRW State Environment Agency to conduct measurements. A plan for field measurements carried out by a panel was set up. It included also measurements taken close to the dwelling-houses of the complainants giving them the assurance that visible attempts of solving their problem would be made.

Field Measurements
Generally, among other things, the basic measurement plan defines the assessment area, assessment squares, measuring points, the assessment period, the measurement duration, the time of measuring during the day, the number of measurements and the code of relevant odor qualities. The assessment area is defined as a circle with a radius of 30 times the height of the stack. The minimum distance from the border of the plant area is 600 m. For measurement purposes, the area is covered by a grid of equidistant measuring points. According to the "directive on odor", assessment squares and measuring points are only required at places where people do not only stay temporarily, as for example residential neighborhoods. The standard distance between two measuring points (grid spacing) is 250 m. In special cases a smaller (100 m, 50 m) or a bigger (500 m) grid spacing is possible. Figure 2 shows the specific adjustment to the requirements in case of the pig farm. As a result, 13 assessment squares consisting of 33 measuring points formed the field of investigation. The numbering of the measuring points and the assessments squares is outlined in Figure 3-1.

The assessment period takes at least half a year and covers cold and warm seasons in equal parts. If time schedule allows, the span can be expanded to one year. During this period, 13 or 26 odor measurements are carried out at each measuring point. Hence follows 52 or 104 records for each assessment square. It is indispensable to get reliable data for the existing conditions that
measurements at the measuring points of one assessment square are taken at different days. In the case of the pig farm a number of 26 measurements per measuring point (104 per assessment square) was chosen. Therefore, odor measurements on site were taken 4 to 5 times per week at different hours during the day.

The starting time of the measurements depends on the specific emission characteristics of the source focused on. If it is a plant with a 24 hours emission time period as for example a livestock farm, it is necessary to collect data in intervals all over the day. Therefore in the case presented the measurements were performed at 2:00 a.m., 6:00 a.m., 10:00 a.m., 2:00 p.m., 6:00 p.m. and 10:00 p.m. One measuring tour consisted of 7 to 9 measuring points and lasted about 3 hours including travel time from point to point. A part of the original measurement plan is shown in Table 3.

For a single measurement a data record form and a stopwatch is required. Each measurement lasts 10 minutes. Longer periods of time are not advisable due to the panel member's declining concentration. During the 10 minutes, each panel member who carries out the measurement is asked the question in intervals of 10 seconds whether the odor is recognisable or not. Hence follows, that this YES - NO question is to be answered 60 times all together. If the answer is positive the panel member has to record his or her observation on the data record form, in the line of the special odor quality code. After ten minutes a maximum of 60 positive answers can be recorded specifying different odor qualities. As a result, the percentage of odor time per measurement duration can be determined for each odor quality.

In connection with this procedure an evaluation follows which is based on the definition of an "odor hour" given in the "directive on odor". One measurement carried out by one panel member is considered as an "odor hour" when the percentage of odor time exceeds 10 % of the duration of the measurement. One basic effect of the definition of an "odor hour" is, that short odor peaks can entail the same amount of "odor hours" as broader peaks over a longer time period. This convention takes into account that short but recurring odor peaks can be more annoying than broader peaks which may allow adaptation.

The definition of an "odor hour" is one of the essential parts of the measurement methods for odor in Germany. It has been in use as a technique of measurement for more than 5 years and it is established in the guideline VDI 3940 in 1993 [5] and in the "directive on odor" with further requirements in 1993 [3]. As a result, the additional evaluation of the ambient odor characteristic is expressed as a percentage of annual hours with odor based on the "odor hour" (percentage of "odor hours" per year = odor frequency).

The method of field measurements requires, that before starting an investigation, the panel members have to be familiarised with the locality as well as the specific odors mentioned in the odor quality code on the data record form. It is recommended during the assessment period to conduct random controls in order to test if the panel member is at the precise measuring point. Besides it is of utmost importance to check the odor sensitivity of each panel member. So recognition tests and odor threshold measurements are necessary. The minimum panel size according to the "directive on odor" is 10. For the investigation presented 17 out of 33 persons were appropriate after testing.

**Ambient Odor Characteristic**

During the investigation in the vicinity of the pig farm 104 records by the panel were carried out (26 per measuring point) over half a year. The data of each single measurement were analysed according to the definition of the "odor hour" mentioned above. The analysis was carried out separately for each of the distinct qualities of the odor code. In Table 4 the total amount of "odor hours" and the percentage of odor frequency are listed relating each measuring point to each quality of the odor code. It is obvious that in some assessment squares the odor frequency of some odor qualities like traffic, vegetation (smelling grass, flowers etc.) and small livestock (without pigs) was higher than the one of the pig farm. But due to the legal framework in Germany (BImSchG, TA Luft, "directive on odor") they are not relevant for evaluation procedure because they are not caused by plants. Only the effects of the emission of the pig farm is of importance as described in Figure 3-2. The largest number of "odor hours" per measuring point and per assessment square were investigated in the north-east of the emitter depending on the prevailing wind direction (south-west). Less "odor hours" were recorded in the other wind directions. It should be noted that at times the
results taken at two measuring points situated next to each other differed more than expected (see Figure 3-2, measuring points 31/12, 14/34, 13/44, 32/42). These variations could be caused by an unknown local emitter, a local flux barrier, or by differences in the sensitivity of the 17 panel members.

In Figure 3-3 the odor frequency per assessment square is described based on the values given in Figure 3-2. It shows that in the residential areas the odor load caused by the pig farm reached a level of approximately 20%. Furthermore taking the assessment square values as a basis allows to smooth local differences without disregarding the odor distribution related to space.

Evaluation Procedure

The aim of the evaluation is to find out whether an annoyance caused by plants can be considered as a significant disturbance (relevance of the annoyance). Before the results shown in Figure 3-2 can be evaluated a transformation according to Equation (1) was necessary in order to calculate the ambient odor characteristic for the existing load \( \text{AOC}_{\text{EXI}} \). In Table 5 the original data (see column "Pig farm", Table 4) and the transformed data are presented. On the basis of either the third or the fourth column of Table 5 (depending on the characteristic of the area) the results were evaluated by using the limit values given in the "directive on odor". For 5 out of 13 assessment squares the value of the ambient odor characteristic \( \text{AOC}_{\text{EXI}} \) exceeded the limit value for trade and industrial zones, for 12 squares the ambient odor characteristic exceeded the limit value for residential and mixed areas (Figure 4). Thus, in this case, the analysis showed that the annoyance related to the pig farm was to be considered as a significant disturbance.

The licensing and surveillance authority responsible concluded that the complaints were legitimate and the attempts of the administration of forcing the emitter to reduce the emissions of the pig farm had a legal basis.

CONCLUSION: THE "DIRECTIVE ON ODOR" - A PRACTICABLE METHOD OF HANDLING ODOR ANNOYANCES

The example above demonstrates that field measurements carried out by panels provide a suitable method of determining the odor load on site. Field measurements allow to measure present odor load expressed as an odor frequency in relation to space. As a part of the system of data acquisition and analysis according to the "directive on odor" the results of these measurements are the basis of the evaluation of the ambient odor characteristic. The exceeding of the limit values by the value of the ambient odor characteristic causes consequences. As a result of the administration taking action emission reduction by abatement techniques could follow. In other cases where measured values do not exceed the limit values the complainants get an appropriate notification by the authority responsible. Which means that the complainants could sue the local authority.

However, today, the method still in common use in Germany is dispersion modeling as it takes less time and money. But the disadvantage is that the results of this method is nothing more than an estimation of the true conditions. Field measurements carried out by panels go far beyond as they are more precise especially in difficult landscapes such as valleys or areas sectionalised by buildings. This method is also advantageous when measurements have to be carried out in the vicinity of sources where the emission type causes problems in applying dispersion modeling. Biofilters, as a non-point source, are an example of that. Therefore if legal binding and safety in planning is required field measurements are becoming more and more common as an effect of the establishing of the "directive on odor".

In general the complete evaluation procedure based on the "directive on odor" has turned out to be an useful and reliable instrument which allows licensing and surveillance authorities to react in differentiated ways. They can adjust both the methodological requirements and the evaluation procedure to the conditions of special cases. Especially the "irrelevance criteria" has been applied several times as it implies the great advantage that if compliance with the legal requirements is verified no further investigation is necessary.

In conclusion, after more than two years of evaluation practice according to the "directive on odor" the experiences are the following:
Methods and their application have been established. This has already had consequences on the accreditation of measuring institutes.

Methods of data acquisition and analysis have been put into direct correspondence to an established evaluation procedure. This has reduced the scope for interpretations in practice.

Licensing and surveillance procedures have been standardised. This guarantees a uniform evaluation practice in NRW and in most German countries.

The measurement and evaluation of odor loads in ambient air as well as annoyances has become more and more important and will certainly be of increasing interest in future.

REFERENCES


2. Technical Instruction on Air Quality Control. (Erste Allgemeine Verwaltungsvorschrift zum Bundes-Immissionsschutzgesetz (Technische Anleitung zur Reinhaltung der Luft - TA Luft)) Federal Ministry for Environment, Nature Conservation and Reactor Safety, Bonn 1986 (GMBI. p. 95). (available in English)


5. Guideline VDI 3940: Determination of Odorants in Ambient Air by Field Inspections. Düsseldorf 1993. (German/English)


Table 1: Limit values for odor in ambient air in different areas.

<table>
<thead>
<tr>
<th>Relative frequency</th>
<th>Residential, mixed area (%)</th>
<th>Trade, industrial zones (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,10</td>
<td>10</td>
<td>0,15</td>
</tr>
</tbody>
</table>

Table 2: Correction factor $c$ dependent on the total number of records ($N$) and the limit values of Table 1.

<table>
<thead>
<tr>
<th>$N$</th>
<th>Residential, mixed area</th>
<th>Trade, industrial zones</th>
</tr>
</thead>
<tbody>
<tr>
<td>52</td>
<td>1,7</td>
<td>1,6</td>
</tr>
<tr>
<td>104</td>
<td>1,5</td>
<td>1,3</td>
</tr>
</tbody>
</table>

Table 3: Measuring plan*.

<table>
<thead>
<tr>
<th>Assessment no.</th>
<th>Month/day</th>
<th>Duration of the measurement</th>
<th>Sequence of the measuring points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>07/06</td>
<td>6:00 a.m.-9:00 a.m.</td>
<td>11, 12, 13 14, 15, 16, 17</td>
</tr>
<tr>
<td>2</td>
<td>07/07</td>
<td>2:00 a.m.-5:00 a.m.</td>
<td>21, 22, 23, 24, 25, 26, 27, 28, 29</td>
</tr>
<tr>
<td>3</td>
<td>07/08</td>
<td>6:00 p.m.-9:00 p.m.</td>
<td>31, 32, 33, 34, 35, 36, 37, 38</td>
</tr>
<tr>
<td>4</td>
<td>07/09</td>
<td>10:00 a.m.-1:00 p.m.</td>
<td>41, 42, 43, 44, 45, 46, 47, 48, 49</td>
</tr>
<tr>
<td>5</td>
<td>07/10</td>
<td>2:00 a.m.-5:00 a.m.</td>
<td>17, 16, 15, 14, 13, 12, 11</td>
</tr>
<tr>
<td>6</td>
<td>07/11</td>
<td>6:00 p.m.-9:00 p.m.</td>
<td>29, 28, 27, 26, 25, 24, 23, 22, 21</td>
</tr>
<tr>
<td>7</td>
<td>07/12</td>
<td>10:00 a.m.-1:00 p.m.</td>
<td>38, 37, 36, 35, 34, 33, 32, 31</td>
</tr>
<tr>
<td>8</td>
<td>07/13</td>
<td>10:00 p.m.-1:00 a.m.</td>
<td>49, 48, 47, 46, 45, 44, 43, 42, 41</td>
</tr>
<tr>
<td>9</td>
<td>07/14</td>
<td>6:00 p.m.-9:00 p.m.</td>
<td>12, 13, 14, 15, 16, 17, 11</td>
</tr>
<tr>
<td>10</td>
<td>07/15</td>
<td>10:00 a.m.-1:00 p.m.</td>
<td>22, 23, 24, 25, 26, 27, 28, 29, 21</td>
</tr>
<tr>
<td>11</td>
<td>07/16</td>
<td>10:00 p.m.-1:00 a.m.</td>
<td>32, 33, 34, 35, 36, 37, 38, 31</td>
</tr>
<tr>
<td>12</td>
<td>07/17</td>
<td>2:00 p.m.-5:00 p.m.</td>
<td>42, 43, 44, 45, 46, 47, 48, 49, 41</td>
</tr>
<tr>
<td>13</td>
<td>07/18</td>
<td>10:00 a.m.-1:00 p.m.</td>
<td>16, 15, 14, 13, 12, 11, 17</td>
</tr>
<tr>
<td>14</td>
<td>07/19</td>
<td>10:00 p.m.-1:00 a.m.</td>
<td>28, 27, 26, 25, 24, 23, 22, 21, 29</td>
</tr>
<tr>
<td>15</td>
<td>07/20</td>
<td>2:00 p.m.-5:00 p.m.</td>
<td>37, 36, 35, 34, 33, 32, 31, 38</td>
</tr>
</tbody>
</table>

* Given are the first 15 assessments.
### Table 4: Odor load of different odor qualities. \( n_{\text{EXI}} = \text{Total amount of "odor hours" per assessment square.} \% = \text{Percentage of odor frequency} \)

<table>
<thead>
<tr>
<th>Assessment square no.</th>
<th>Pig farm</th>
<th>Manure</th>
<th>Small livestock</th>
<th>Traffic</th>
<th>Domestic</th>
<th>Vegetation</th>
<th>Other odors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n_{\text{EXI}}</td>
<td>%</td>
<td>n_{\text{EXI}}</td>
<td>%</td>
<td>n_{\text{EXI}}</td>
<td>%</td>
<td>n_{\text{EXI}}</td>
</tr>
<tr>
<td>1</td>
<td>19</td>
<td>18.3</td>
<td>1</td>
<td>1.0</td>
<td>20</td>
<td>19.2</td>
<td>3</td>
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</table>

* Total number of records \( N = 78 \)

### Table 5: Odor load caused by the pig farm. \( n_{\text{EXI}} = \text{Total amount of "odor hours" per assessment square.} \ AOC_{\text{EXI}} = \text{Ambient odor characteristic of the existing load for different areas expressed as a relative frequency according to Equation (1).} \)

<table>
<thead>
<tr>
<th>Assessment square no.</th>
<th>&quot;Odor hours&quot; ( n_{\text{EXI}} )</th>
<th>Residential, mixed area ( AOC_{\text{EXI}} )</th>
<th>Trade, industrial zones ( AOC_{\text{EXI}} )</th>
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</table>

* Total number of records \( N = 78 \).
** "Odor hours" extrapolate to \( N = 104 \).
Field measurement with panels

Result of field measurement

Dispersion modeling

Result of the estimation based on olfactometry and volume stream detection

Ambient odor characteristic
(percentage of odor hours = odor frequency)

Evaluation of the ambient odor characteristic applying limit values

Figure 1: The system of data acquisition and analysis as described in the "directive on odor".

Figure 2: Assessment area, assessment squares, measuring points and distance to the source.
Figure 3-1: Numbering of measuring points and assessment squares
3-2: Amount of "odor hours" related to the pig farm
3-3: Percentage of "odor hours" related to the pig farm
Figure 4: Evaluation of the ambient odor characteristic (AOCExi) applying the limit values.

- AOC\textsubscript{xi} \leq 0.10
- 0.10 < AOC\textsubscript{xi} \leq 0.15
- AOC\textsubscript{xi} > 0.15