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Reliability of the Results of an Odour Field Inspection - Grid Method - based on the Sample of 104 Single Measurements within one Year

Janina Güntzel*, Bettina Mannebeck, Heike Hauschildt

Olfasense GmbH, Schauenburgerstr. 116, 24118 Kiel, Germany

jguentzel@olfasense.com

The determination of odour in ambient air by field inspections using the grid method is a method that has been used in Germany for decades to determine the frequency of exposure to odours in an impact area. The method which is currently described in EN 16841-1:2016 is a statistical survey which is applied over a sufficiently long period of time. It delivers a representative map of the exposure to recognizable odour(s) with its distribution over the assessed area. Within this paper the principle of measurement will be briefly described, as well as the challenges that might occur during a project and the possibilities that arise from the detailed measurement of odour frequencies in the impact area. Often the question arises whether the sample of 104 single measurements per assessment square and year is sufficient. Olfasense GmbH has been carrying out yearly field surveys in the vicinity of an industrial plant since 2009. In contrast to the procedure described in EN 16841-1:2016-11, the field surveys take place on a daily basis in this project. This results in 365 single measurements per assessment square and year. The time of day is varied according to the standard.
This extensive data set including 365 single measurements is used as reference survey. Subsequently, the same data was randomly divided into 3 individual data sets (sample surveys 1 to 3), each including 104 single measurements. For each data set the results including the measurement uncertainty according to EN 16841-1:2016 are evaluated for the single assessment squares. With a comparison of the reference survey (365 measurements/year) with each of the sample surveys (104 measurements/year) the reliability of each sample survey can be determined. As the sample surveys represent the required scope of measurement according to the European Standard EN 16841-1:2016 a validation of the usual extent could be performed. The results of this evaluation show that 104 single measurements per assessment square within one year, as reflected in the sample surveys, are sufficient to make a statement on the compliance with the permissible odour exposure in the impact area, taking into account the measurement uncertainty contributions.

1. Description of the field measurement - grid method - and the procedure according to EN 16841-1:2016

The method used in this manuscript is based on the European Standard EN 16841 Part 1: Grid measurement (EN 16841 Part 1 2016). This method describes the determination of the spatial distribution of ambient odour exposure. The unit of the method is the frequency of odour hours which is used to assess the odour exposure on the defined grid squares. If the odour reaches or exceeds 10 % of the measurement duration, an "odour hour" occurs. Each single measurement is a 10-minute interval consisting of 60 10-second intervals. At each 10-second interval the panel member assesses one breath of air and evaluates if an odour is present or not, and the type of odour. 6 or more 10-second intervals with presence of odour indicate one odour hour (10% or more of the total assessments). The measurement uncertainty is defined by varying the number of the 10-second intervals from which the odour hour is reached. This means that the lower limit of the measurement uncertainty is calculated by counting a single measurement as odour hour when more than 8 (9 or more) 10-second intervals with odour have appeared. This equals a percentage of 15% positive answers within the 10 minutes of the single measurement.

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The upper limit of the measurement uncertainty is calculated by counting a single measurement as odour hour when more than 2 (3 or more) 10-second intervals with odour have appeared. This equals a percentage of 5% positive answers within the 10 minutes of the single measurement.
In general, as predetermined in the European Standard EN 16841- Part 1, the survey period is one year, consisting of 104 single measurements per assessment square (EN 16841 Part 1 2016, VDI 3940 Part 1 2006). Often the question arises whether the sample size of 104 single measurements per assessment square and year is sufficient to gain a complete insight of the odour impact.
Olfasense GmbH has been carrying out field inspections in the vicinity of an industrial plant since 2009. In this inspection project the single measurements take place on a daily basis, resulting in 365 single measurements. This represents a contrast to the procedure (104 single measurements) as described in EN 16841-1:2016. The time of day is varied according to the standard. We use the data from the daily field inspections for the evaluation of the reliability with regards to the number of single measurements carried out. In the following, the survey containing all 365 days of inspection is referred to as “reference survey” (Data Olfasense GmbH 2018-2020).
In Germany the limit value for odour exposure in residential areas is fixed to 10% of the yearly hours according to GOAA 2008. The calculated frequency of odour hours on each assessment square is compared this limit value to evaluate the conformity of the situation with the limit values.The inspection comprises 8 assessment squares (A-H) with a total of 15 measurement points. In the following, the reference survey consisting of 365 single measurements is compared with three sample surveys consisting of 104 single measurements each. This comparison was carried out for three different years. Figure 1 shows the location of the assessment squares as well as the location of the measurement points in the assessment area (anonymised).

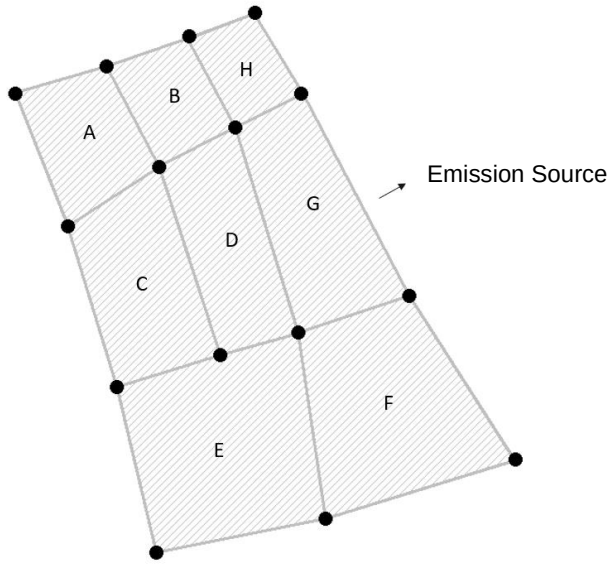

Figure 1: Location of the assessment squares and measurement points in the assessment area [simplified representation through anonymisation] (Data Olfasense GmbH 2018-2020).

The number of panel members and assessments of each individual year is shown in the following table. In agreement with the client, cancelled single measurements have not been repeated on another day.

Table 1: Number of panel members and assessments during the assessment period (2018-2020).

Year	Number of panel members	Number of assessments	Number of cancelled assessments
2018	22	365	-
2019	19	362	3
2020	15	362	3

The results of each reference survey were divided into three equally distributed sample surveys. For each of the three sample surveys, 104 single measurements within the time range of the reference survey were selected in turn, so that every first day was assigned to sample survey 1, every second day to sample survey 2 and every third day to sample survey 3. In each month, one day was not considered. The statistical requirements for the distribution of weekdays and times of day are met for the reference as well as for each of the three sample surveys. (Data of grid measurement Olfasense GmbH 2018-2020).

2. Investigation of the results with regard to the reliability of three sample surveys in comparison to the reference survey

The evaluation of the results was carried out over a period of three years (2018-2020). The relative odour frequencies on the assessment squares were calculated from the measurement results. The odour frequencies per year of each of the three sample surveys were compared with the odour frequencies of the reference survey. Subsequently, the results including the measurement uncertainty of the surveys were considered. The measurement uncertainty is evaluated by determining the upper limit – odour hours arising from single measurements with more than 2 positive observations (counting threshold 3 corresponding to 5 % positive observations) – and the lower limit – odour hours arising from single measurements with more than 8 positive observations (counting threshold 9 corresponding to 15 % positive observations). An observation is considered “positive” when a recognizable odour is detected. The percentage of positive observations out of the total number of observations is called “percentage odour time”.

The evaluation of the results was carried out according to the specifications of the Guideline on Odour in Ambient Air (GOAA 2008) which was valid at the time of evaluation. The frequency of odour hours on each assessment square is compared with the odour impact values that have to be applied. For the project considered in this manuscript, the impact value refers to 10% of the annual hours, with odour hour frequencies of more than 10% representing an exceedance of the odour impact value (GOAA 2008). This impact value is applied to residential areas.

The calculation of the uncertainty is carried out according to DIN EN 16841-1 [1] on the basis of the variation of percentage odour time. By definition, the odour hour criterion is fulfilled if the percentage odour time reaches or exceeds 10 % (6 or more positive observations out of 60 total observations). The same calculation is made using different percentage odour times to determine the upper and lower limits for the number of odour hours. The greater the difference between the measurement result and the applied odour impact value, the lower the probability of an error in the evaluation. Accordingly, the uncertainty range can be determined from the determination of these upper and lower limits. This means a larger survey scope results in a narrower uncertainty range (EN 16841 Part 1 2016).

Figure 2 shows the distribution of odour hour frequencies including the uncertainty range of the total odour exposure for the year 2018.

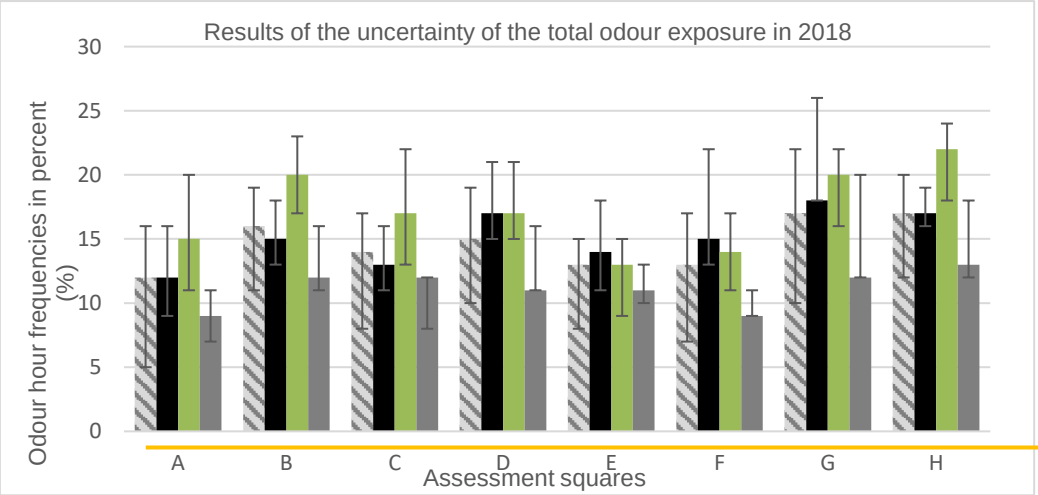

Figure 2: Results of the total odour exposure including the uncertainty range for the measurement period of 2018; the hatched grey bar represents the “reference survey”, the black bar sample survey 1, the light green bar sample survey 2 and the dark grey bar sample survey 3. The orange line shows the odour impact value.

For the year 2018, it becomes clear that the results of the three sample surveys are within the result of the reference survey including the uncertainty range on six of the eight assessment squares. Only on the assessment squares B and H, the results of sample survey 2, are higher than the uncertainty range of the reference survey. With regard to the compliance with the odour impact value, taking into account the uncertainty range of the reference survey, there is no deviating conclusion for any of the assessment squares. If the uncertainty range of the reference and the sample surveys were neglected, the conclusion regarding compliance with the odour impact value on assessment squares A and F would change from non-compliant to compliant for sample survey 2.
It is noticeable that the results of sample survey 2 are equal to or greater than the results of the reference survey on all assessment squares, while sample survey 3 shows lower odour hour frequencies than the reference survey on all assessment squares.
Figure 3 shows the distribution of odour frequencies including the measurement uncertainty for the total odour exposure for all variants for the year 2019. The results for the year 2019 show a similar distribution as for 2018.

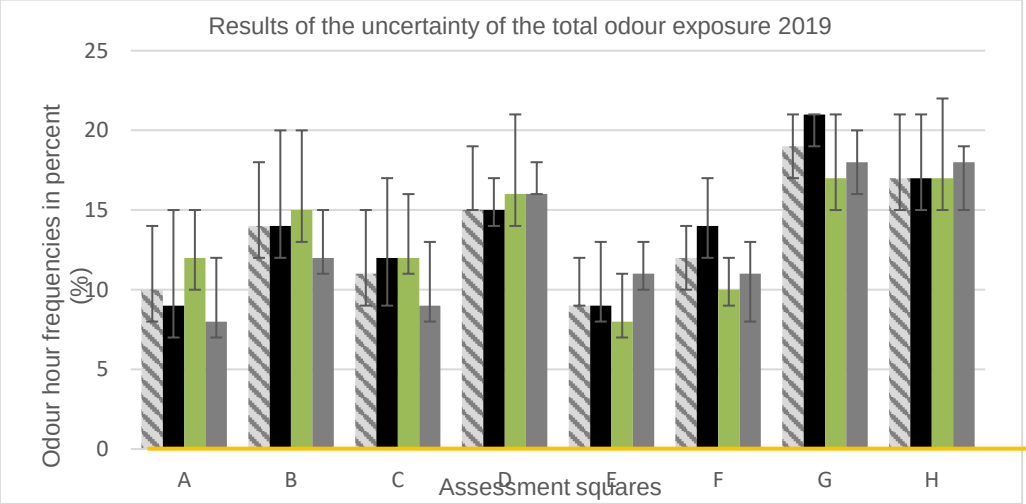

Figure 3: Results of the total odour exposure including the uncertainty range for the measurement period of 2019; the hatched grey bar represents the "reference survey", the black bar sample survey 1, the light green bar sample survey 2 and the dark grey bar sample survey 3. The orange line shows the odour impact value.

For the year 2019, it is apparent that the results of the three sample surveys are within the result of the reference survey including the uncertainty range on seven of the eight assessment squares. Only in assessment square E the results of sample survey 2 are below the uncertainty range of the reference survey. With regard to the compliance with the odour impact value, taking into account the reference survey's uncertainty range, there is no changed conclusion for any of the assessment squares. Neglecting the uncertainty range of the reference survey and the sample surveys, the conclusion regarding compliance with the odour impact value would change from compliant to non-compliant on assessment square A for sample survey 2 and on assessment square E for sample survey 3. On assessment square C for sample survey 3 and on assessment square F for sample survey 2, the conclusion would change from non-compliant to compliant.
Finally, Figure 4 shows the distribution of odour frequencies including the measurement uncertainty for the total odour exposure for all variants for the year 2020.
The results for 2020 show that the three sample surveys are within the result of the reference survey including the uncertainty range on four of the eight assessment squares. On the assessment squares B, E, F and G, the results of some of the sample surveys are below the uncertainty range of the reference survey. With regard to compliance with the odour impact value, taking into account the uncertainty range of the reference survey, the conclusion changes from non-compliant to compliant only for two of the assessment squares, i.e. for B and G. If the uncertainty range of the respective deviating sample surveys is taken into account for this consideration, the original conclusion of non-compliance would have to be drawn similarly to the reference survey. Neglecting the uncertainty range of the reference survey and the sample surveys, the conclusion regarding compliance with the odour impact value would change from compliant to non-compliant on assessment square A for sample survey 1 and on assessment square C for sample survey 3. On assessment square B for sample survey 1 and on assessment square G for sample survey 3, the conclusion would change from non-compliant to compliant.

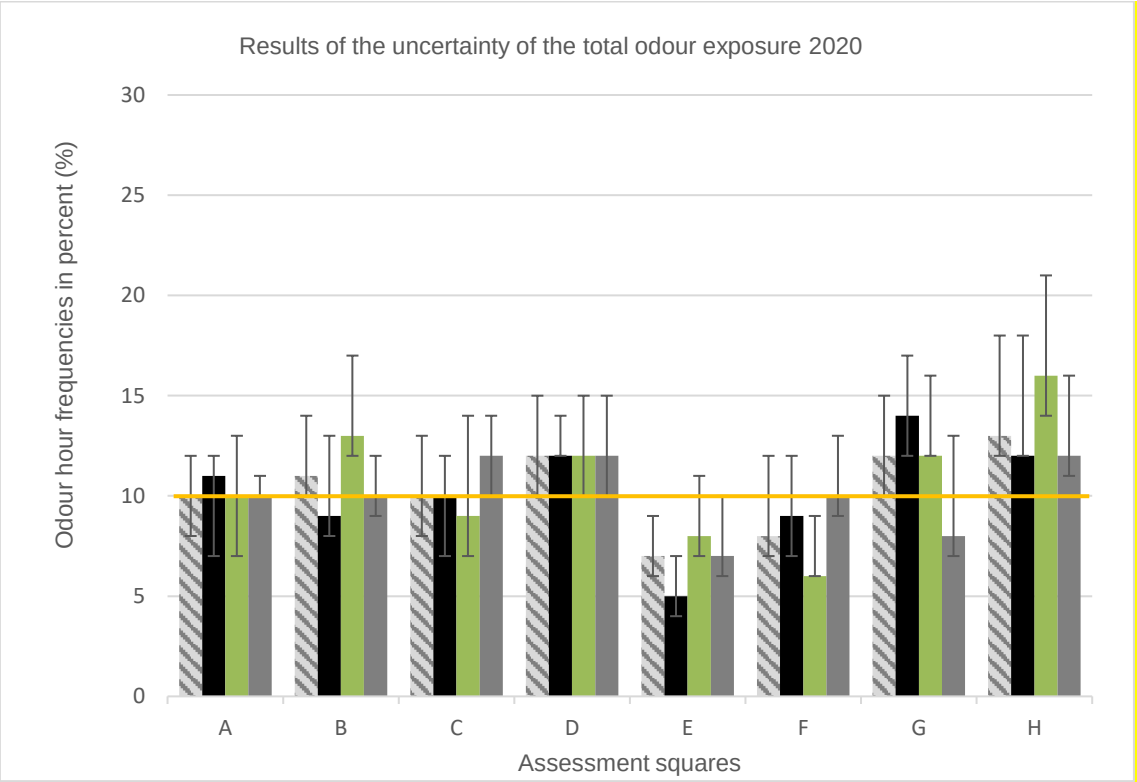

Figure 4: Results of the total odour exposure including the uncertainty range for the measurement period of 2020; the hatched grey bar represents the "reference survey", the black bar sample survey 1, the light green bar sample survey 2 and the dark grey bar sample survey 3. The orange line shows the odour impact value.

3. Discussion

The comparison of the results of the frequency of exposure to odours in the considered three-year period shows a slight deviation of the mean values of the exposure of the sample surveys compared to those of the reference survey. In contrast, the upper and lower limits of the sample surveys vary more strongly, which has been expected.

With regard to the reliability of the conclusion of field inspections using the grid method, it can be stated that on the assessment squares where the sample surveys deviate from the reference survey, the conclusion regarding the odour impact value does not change when taking the uncertainty range into account.

Also, the question of whether the exposure limit value is complied with or exceeded, does not change when the uncertainty ranges are taken into account. For example, in 2018, the exposure limit value is exceeded on all assessment squares in the reference survey, but is complied with for individual assessment squares (A and F) in the sample surveys. Taking into account the uncertainty range on these squares, the exposure limit value is to be evaluated as exceeded. A marginal difference arises only in 2020 for assessment square E, where the statement of all results, reference survey and samples, coincides with "compliance with the exposure limit value" and only when applying the uncertainty range of sample 2 a non-compliance with the exposure limit value would be achieved. In this case, the individual inspections must be checked in detail.

Considering the measurement uncertainties, the fluctuation in all three years can therefore be considered insignificant with regard to the reliability of the conclusion.

4. Conclusion

The grid measurement method for assessing the frequency of odour exposure in the vicinity of an industrial plant is based on random measurements within a measurement period. According to DIN EN 16841-1:2016, the scope of this random sample is 104 individual measurements within one year. The question arises as to whether this sample is sufficient to draw a reliable conclusion on the exposure limit in the assessment squares. The results of the last three years of a daily field inspection survey, consisting of 365 individual measurements, as well as the results of three sample surveys, each consisting of 104 individual measurements, were evaluated.

Afterwards it was examined to what extent the sample surveys lie within the measurement uncertainty of the reference survey and whether there are any changes regarding the conclusion of compliance or non-compliance of the exposure limit value.
The evaluation of the results shows that the three sample surveys are within the uncertainty range of the results of the reference survey, except for some individual assessment squares. At the same time, it emerges that, taking into account the uncertainty contributions of the reference survey and the determined samples, there is no change in the statement of compliance or non-compliance with the exposure limit value according to GOAA (nowadays Technical Instruction on Air Quality Control (TA Luft)) for any of the assessment squares, not even for the exceptions considered.
Accordingly, it is to be noted that the random sample of 104 measurement days in one year is sufficient to make a statement on compliance with the exposure limit value, taking into account the measurement uncertainty contributions.

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