State of the Art of Odour Measurement

Prof. Dr.-Ing. Franz-Bernd Frechen,
Head, Dept. Of Sanitary and Environmental Engineering,
University of Kassel, Kurt-Wolters-Str. 3,
34125 Kassel, Germany,
frechen@uni-kassel.de

Keywords
Olfactometry, Sampling, Odour Emission Capacity OEC of liquids

Abstract
As odour is increasingly annoying closed-by residential areas, many approaches were made in the past year, developments achieved and research work done in order to better understand the problem and especially in order to better protect people from severe annoyance. A main aim within this progress – and a basic need – is the development of reliable, repeatable and recognized odour measurement method and procedures. Major parts herein are sampling of odour emissions and the procedure of measurement. These have to serve for the assessment of impact and subsequent definition of odour impact prevention policies. In addition, the characterisation of odour containing liquids by means of the odour emission capacity OEC is explained, and recent developments and results of research work are presented.

1. Introduction

Odour has many facets and can affect man lightly up to seriously, resulting in strong annoyance or even severe health problems. Usually the classical “odour” discussion does not deal with the health aspect rather than with the annoyance aspect of odorants present in the ambient air.

In order to establish a policy and a system to protect man from illegal annoyance caused by odour impact, it is essential to a) measure the odour and b) measure the impact. This paper deals with the odour measurement part, and does not deal with the impact of offensive odours and its resulting annoyance. Annoyance-related work has been carried out to a remarkable extent in Germany in connection with the development of legal standards and governmental policy concerning combat of offensive odours. Winneke has contributed a lot to this, and the reference Winneke et al. (7) may just serve as a younger example of this work. These activities have led to a governmental guideline inside Germany called the “Directive on Odour in Ambient Air”, discussed since the late 80ties and issued as a regulation in the majority of states inside Germany in 1998, as explained by Frechen (3). The “Directive on Odour in Ambient air”, see Both (2), draws the line between nuisance that has to be accepted and annoyance that is not acceptable and thus illegal.

Odour measurement has to help gaining the basic values and numbers that are neeeded for assessment of the community problem that is associated with odour impact.

With regulations existing in several countries of the EU, the European Committee for Standardization CEN decided to issue an European Standard on determination of odour concentration which was finally approved by CEN in December 2002 (1). This is the important key document when discussing odour measurement in the EU, influenced by and vice versa influencing research work conducted in Europe in this field. Thus, frequent reference to the EN 13725 will be found in this paper.
At this time, several aspects of odour measurement are under intense discussion regarding the state of the art in odour measurement. Main topics to be discussed in the presentation more in detail are

- Sampling.
- Olfactometry.
- Odour Emission Capacity of liquids.

2. Sampling

As with all other measurements, accuracy of sampling is a cornerstone for correct results. In addition, it has to be accepted that odours are gaseous emissions, thus sampling in general has to meet all the requirements that are applicable for any analytical measurement of gaseous compounds. The result of all sampling and measurement effort must be the odour emission rate of the respective source, given in odour units per time, e.g. given in o.u./s or Mo.u./h.
According to EN 13725 (1), "Sampling aspects are included in the structure of this Standard, although further research is necessary to complete this issue". Considering the configuration of the odour source, it can be distinguished between sources with a measurable outward airflow (active sources) and sources that do emit odours but have no measurable outward airflow (passive sources).
At active sources, sampling is relatively easy. Outward airflow has to be measured by standard procedures or determined by other means (operator documentation, process control system outputs) and sampling must assure a representative mixture of the emitted air in order to characterize the behaviour of the source. This can be achieved by applying a total cover to the source in order to prevent the sample from being influenced from the ambient air during sampling, see Fig. 1.

Fig. 1 Sampling at an active area source - biofilter

If the source, instead of a stack or a small area source, is a big area, e.g. a surface of a big biofilter or aerated tank, which cannot be covered totally, it is necessary to perform incremental sampling by covering several parts of the active source without changing the pressure conditions (and other, e.g. temperature) and perform sampling here. This may be done with measurement (biofilter) or without measurement (aeration tank) of the outward airflow in the respective separated, covered part of the source. The actual discussion mainly deals with minimum requirements for this type of sampling in terms of percentage of the area that must be covered.

A major problem is encountered when the source obviously emits odour but is a surface without measurable outward airflow. This source type, called “passive source”, is frequently found on wastewater (sedimentation tanks, thickeners etc.) and waste (landfill surfaces etc.) facilities, agriculture (manuring etc.) and others.

However, even in this case it is necessary to measure the odour emission rate originating from the respective passive source. Thus, the sampling method must be appropriate. Different sampling methods were tested throughout the last decades, and the main representatives are

- Indirect measurement: micrometeorological methods using different atmospheric dispersion models.
- Direct measurement: hood methods, commonly divided into static flux chambers, dynamic flux chambers and wind tunnels.

A very good presentation and comparison of these two different types is given by Stuetz (5).

Indirect measurement is not very common and is not used in Germany, except by means of direct field inspections with a trained test person panel using the plume measurement method as described in the VDI-guideline 3940 (6).

Concerning direct measurement, it can be stated that static flux chambers, operating near equilibrium state, are not suitable for producing relevant information on the odour emission rate.

Dynamic flux chambers, usually round with a radial air inlet, also play a minor role today, as the shape of the chamber as well as the radial air inlet inhibit a good control over the flow pattern inside the chamber. However, by using the area-related sweep rate, expressed in sweep air volume per time and per area covered by this hood, and the emission concentration it is possible to calculate the emission rate of the surface where the sampling is done. In general, looking at the different types used, a common feature is a very small airflow, resulting in a very low area-related sweep rate.

Wind tunnels usually cover a rectangular area with a length-to-width-ratio that should be above 2:1, and as researches show, an increasing ratio gives better results, as a more longitudinal stretched tunnel can be better controlled and shows more stable flux conditions. Different types of tunnels, mainly differing in size and shape of inlet and outlet, are used today. Fig. 2 shows an example of a

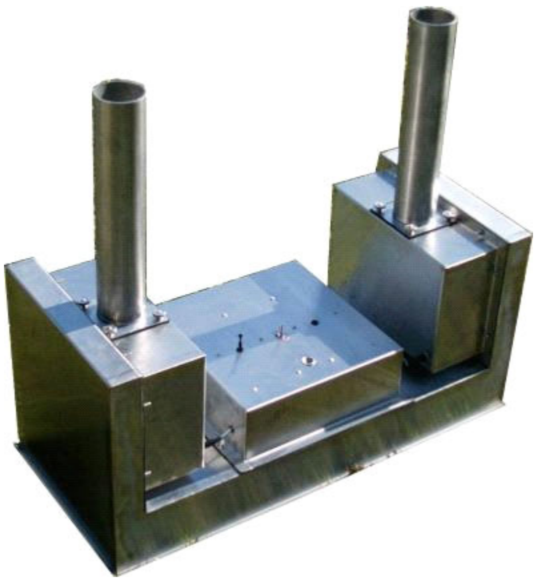

Fig. 2 Compact wind tunnel

wind tunnel with inlet and outlet duct connected to the housing for the fans, one each at inlet and outlet. In the middle, atop the tunnel itself, batteries and other electrical equipment is placed.
Due to the shape of the wind tunnels and due to the fact that odourless air is fed into one of the two narrow sides of the tunnel and extracted at the opposite side, a directed flow is achieved and thus, besides the area-related sweep rate, the sweep flow velocity is an important feature. With most wind tunnels, area-related sweep rates are about 400 $m^3\ m^{-2}\ h^{-1}$ and horizontal velocities are in the range of 0.1 – 0.5 $m\ s^{-1}$. Of course, the sweep flow velocity is influenced by the tunnel height. Thus, with the same area-related sweep rate it is possible to increase the sweep flow velocity by reducing the tunnel's height. Besides this, low tunnels are advantageous due to their better behaviour concerning flow pattern and vertical homogenity.
The sampling box we have been using for many years includes a combination of the advantageous properties of the dynamic flux chamber and the conventional wind tunnel. This system or sampling box may be called a “low speed wind tunnel”. Stuetz (5) calls it a dynamic flux chamber which is incorrect due to the flow pattern in the tunnel.
As the description implies, the shape is rectangular with different sizes of between 0.60 m and 1.0 m in length and 0.20 m and 0.33 m in width. Different from other wind tunnel systems, a sweep airflow of about 30 $L\ min^{-1}$ is used, resulting in area-related sweep rates between 5 $m^3\ m^{-2}\ h^{-1}$ and 18 $m^3\ m^{-2}\ h^{-1}$, depending upon the size of the respective sampling box. Using heights around 0.10 m, the velocity inside the tunnel is in a range of 0.01 $m\ s^{-1}$ and 0.03 $m\ s^{-1}$ which is significantly lower than it is found in conventional wind tunnels.
A comparison based upon typical properties of the different types of sampling devices is given in Table1.

Table 1 Comparison of different sampling devices

	dynamic flux chamber	**low speed wind tunnel**	**conventional wind tunnel**
shape	round	rectangular	rectangular
flow pattern	mixed	laminar	laminar/turbulent
height	medium	low	medium/large
area related sweep rate	low < 40 $m^3\ m^{-2}\ h^{-1}$	low < 40 $m^3\ m^{-2}\ h^{-1}$	high 400 $m^3\ m^{-2}\ h^{-1}$
airflow speed (horizontal)	./.	low 0.01 – 0.03 $m\ s^{-1}$	high 0.1 – 0.5 $m\ s^{-1}$
problem with low emission sources	no	no	yes

Due to boundary layer theory, it is likely that low wind speeds inside a sampling system will result in a slight underestimation of the real emission process. However, as olfactometric measurement has a lower limit of reliability and accuracy, severe problems arise when samples from a low emission source are collected via a con-

ventional wind tunnel system, resulting in very low odour concentrations which will make it very likely that odour measurement problems will arise. The choice of the respective sampling system must take these circumstances into consideration.
Another important point is that due to meteorological laws problems in ambient air are always most likely with very low wind speeds or even calm situations. In those situations, with a stable atmospheric condition, transmission is most critical as dilution during transmission is very poor. Thus, measurement should take this into account by using low wind speed in the tunnel system.
At this moment, research work is done at the Kassel University to describe the behaviour of low wind speed tunnels more in detail. Results will be published soon.
Concerning the size of the sampling equipment, a compromise between representativeness and practicability will be necessary. Heights of more than 0.15 m should be avoided. Sizes of area covered by the unit range between 0.1 m^2 and 1 m^2 which may define the lower and the upper limit in the above mentioned sense.
As the EN 13725 explicitly does only include "sampling aspects" and indicates the need of further research and standardization, in the German Engineers Association VDI we just now started a new expert commission on the topic of sampling. Results should be available in 2004.

3. Olfactometry

Concerning olfactometry itself, the two main movements today are standardization of the measurement method, as was done by the EN 13725 standard but also is a hot topic at CASANZ for their area, and development of new olfactometric devices.
Standardization was finished at the end of 2002, as far as the EU is concerned. The final issue of the long discussed EU standard at this time has come to an end concerning the official work but of course will steadily develop further, so it can be expected that within the next 5 to 8 years the standard will be revised according to the experience collected in the meantime.
Looking at the devices, it is sure that standards do have an impact on their design. This is due to the fact that different presentation and evaluation methods – yes/no-method or forced-choice-method – are possible. This is also due to the fact that the EU 13725 requires valid answers from at least 4 panelists after evaluation. Due to the evaluation method it is possible that a panelist may be out of the tolerable range on that specific measurement day, thus it might be advantageous to operate with 5 panelists.
However, most olfactometers today have 1, 4 or 8 sniffing places. A "sniffing place" is formed by one sniffing port per panelist (yes/no-method) or by two sniffing ports per panelist (forced-choice-method). Fig. 3 shows an example of such a

Fig. 3 Example of a 1-sniffing-place forced choice olfactometer (with two sniffing ports)

one-sniffing-place two-sniffing-port olfactometer designed for the forced choice method. Flow control in the past was done by needle valves which were to be operated by the test leader. Mass flow controllers involving a control loop for the airflow showed to be too sensitive and thus too inaccurate concerning the preparation of a defined mixture of the two airflows – sample and odourless air – and thus are not widely used today.

Today the use of saphir orifices is possible to achieve a very constant and stable, defined airflow which is essential for a precise measurement. One of the advantages is that with this type of flow controlling it is possible to let the measurement be done automatically with an appropriate PC-based measurement process controller. However, PC's today are needed in any case for the data management and calculations according to the standards so a PC will always be present. Thus, there is no problem to use the PC for measurement process control plus data acquisition.
Fig. 4 shows a TO 8 device made by ECOMA suited for four panelists doing yes/no measurement. The new series can contain up to 8 sniffing ports allowing for a simultaneous 8-panelist yes/no-measurement or a simultaneous 4-panelist forced-choice-measurement. According to the manufacturer, more than 200 olfactometers are sold worldwide.

Fig. 4 Example of a four-sniffing-place yes/no olfactometer (in total 4 sniffing ports)

4. Odour Emission Capacity (OEC) of liquids

Although olfactometry always deals with (foul) air samples, a characterisation of liquids concerning their content of odorants is urgently needed. By stripping the odorants from a liquid sample, taking samples at suitable times after beginning of the aeration with odourless air and, after the test itself, calculating the integral of the odour units that were stripped from the sample, one can calculate the amount of odour units that can be stripped from one cubic meter of liquid, called the Odour Emission Capacity OEC, as introduced by Frechen and Köster (4). Thus, the OEC is given in o.u. m^{-3}_{Liquid} and characterises the relevance of the respective liquid with respect to odour. The OEC is very important in identification of the main liquid odour sources and is also decisive

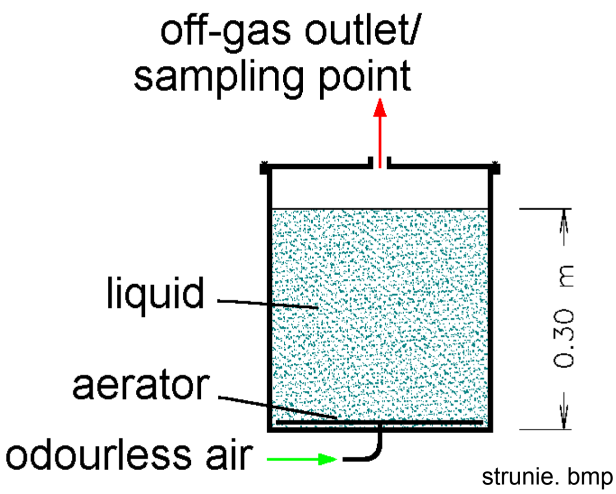

Fig. 5 sketch of the OEC test reactor

concerning the selection of possible measures against odour nuisance resulting from liquid streams.

Fig. 5 shows a sketch of the reactor wherein the OEC test is performed. Of course, besides olfactometric measurement the samples collected from the off-gas outlet should also be analysed concerning analytical measurable compounds such as ammonia, hydrogen sulphide etc., resulting in emission capacities EC for the respective compound and expressed in mg m^{-3}_{Liquid}. The use of this measurement is just beginning to be recognized, and in the presentation some of the advantages will be presented and values will be given.

Fig. 6 shows the results of a test for foul sewage from a long sewer system. It is evident that we see a H_2S-problem in this case.

In Germany, it is discussed whether to introduce this EC measurement as a way to set standards for indirect discharges of industrial facilities into the publicly owned sewer system in order to minimise odour load.

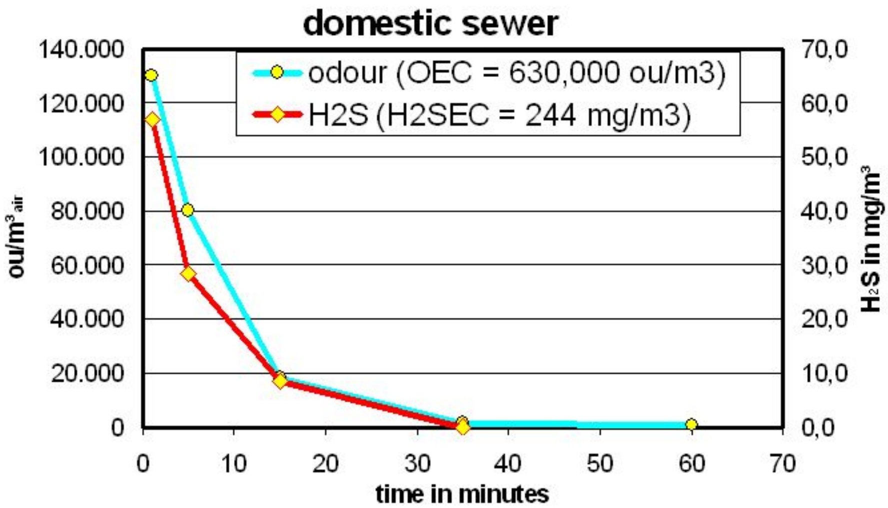

Fig. 6 sample run of OEC test

References

1) AA: Air quality － Determination of odour concentration by dynamic olfactometry, EN 13725:2003(E), CEN, Brussels, March 2003
2) Both, R.: Odor regulations in Germany – A New Directive on Odor in Ambient Air, Proceedings of an International Specialty Conference of AWMA, Bloomington, MM, September 13-15, 1995
3) Frechen, F.-B.: Regulations and policies, 2001, in: Odours in wastewater Treatment, pp. 16-30, edited by R. Stuetz and F.-B. Frechen, IWAP, London
4) Frechen, F.-B. and Köster, W.: Odour Emission Capacity of Wastewaters – Standardization of Measurement Method and Application. Wat. Sci. Tech. Vol. 38, No. 3, S. 61-68
5) Stuetz, R.: Review of Odour Sampling an measurement, Cranfield University, 2002
6) VDI: Determination of Odorants in Ambient Air by Field Measurements, VDI Handbook on Clean Air, Volume 1, Beuth Verlag, Berlin, October 1993
7) Winneke, G.; Frechen, F.-B.; Both, R.; Steinheider, B.: Psychology of odour annoyance: linear and non-linear dose-effect-relationships, memory effects and psychosomatics, (in German) 1995