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Emission of Odours from Sewer Systems: Possible Countermeasures and Quantification of their Efficiency using the Odour Emission Capacity OEC

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Malodours from sewer systems and the annoyance resulting from them gain more and more attention. Possible countermeasures include, but are not restricted to: dosing of chemicals, introducing technical ventilation including waste air treatment, change of system essentials, discharge restrictions to industrial sources. All measures that aim to modify the odorants content of the wastewater itself, mainly chemical dosing, show the problem that up to now proof of efficiency and proof of appropriate dosing were difficult to obtain. Thus, it is essential to measure the odorants concentration in the liquid phase. This can be done by using the Odour Emission Capacity (OEC) method. This method, including sensory measurement via Olfactometry, is in use by DESEE since more than 10 years. An automated, nearly-online version is under research at the Bottrop sewer in preparation for its use at the Emscher sewer system including measurement of sulphide content as well as utilizing electronic noses for automated OEC measurement.

1. Introduction

In recent years problems caused by malodours from sewer systems gain more and more attention. This is due to several reasons as more centralized sanitation systems which cause long and flat sewers, oversized sewer diameters, decreasing wastewater discharge both from industry and households, extended use of stormwater infiltration and others.

The result is an increasing number of complaints against offensive odours. This may already start at the sewer system, as the source of the odour emission, the wastewater conveyed in the system, may give rise to the phenomena. However, all installations downstream, including wastewater treatment plants (wwtp) may emit odours.

Looking at a sewer from a more general point of view, a scheme of the relevant processes is given in Figure 1.

The primary sources of odorants generation in a sewer are
(1) discharge of odorous wastewater into the sewer, mainly done by industries, and
(2) formation of odorants in the sewage due to unfavourable process conditions, usually due to lack of oxygen with subsequent anaerobic zones or times

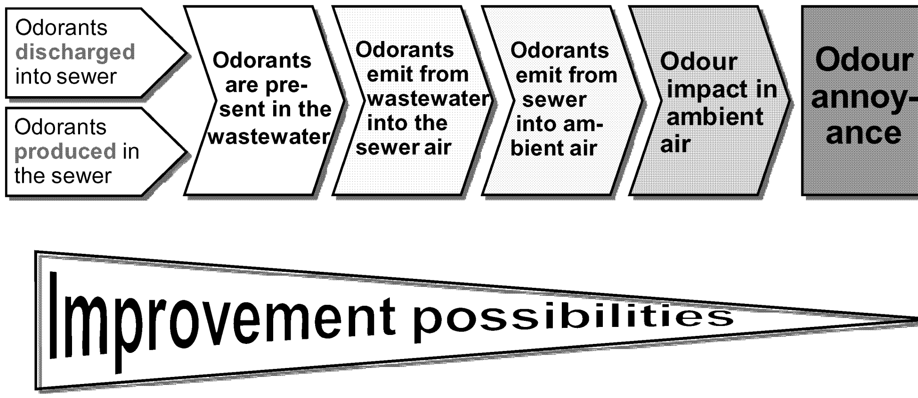

Figure 1. Development of odours in sewers and their possible impact on the environment.

Once odorants are introduced or formed and thus are present in the liquid, the next step is emission of these substances into the sewer air. If so, the sewer air may leave the sewer due to natural or – in rare cases – artificial ventilation. This leads to an odour impact near the sewer system, and if the environment is a sensitive one like housing area etc., then annoyance will occur due to this impact. The further right in this chain of steps, the minor are the possibilities to tackle the problem and improve the situation. This makes it absolutely evident that it is essential to measure the facts, i.e. the amount of odorants to be dealt with, as early as possible (as far to the left of Figure 1 as possible), thus, measure the OEC in the liquid phase. As an example, the sewer air of a sewer showing low flow and low turbulence may be not very high loaded with odorant even if the sewage is highly odorous. Thus, measurement in the sewer air will give no hint on the detrimental potential of the liquid. But when turbulence occurs, e.g. at a drop, a pumping station or even a manhole, release of odorants from the liquid phase into the sewer air is highly relevant if there are many odorants in the wastewater itself.

2. Measuring Odours

2.1 Measuring Odours in Air – EN 13725:2003

In Europe a standard methods exists for the measurement of the odour concentration in air, which is laid down in EN 13725:2003 (2003) entitled “Air quality - Determination of odour concentration by dynamic Olfactometry”. This is a sensory method, using test persons as the detector. The dilution factory necessary to reach the odour threshold of the panel is the cornerstone of this method. The odour concentration of air samples equals this dilution factor and is the “number of European odour units in a cubic metre of gas at standard conditions”. Its symbol is cod and the unit is ou_E/m^3.

2.2 Measuring Odours in Liquids – The Odour Emission Capacity OEC

2.2.1 Definition and Evaluation

With emissions from liquids into the gaseous phase, many factors influence the rate of liquid-to-gaseous mass transfer, such as temperature, degree of turbulence, concentration of sub-stances in the air and others. However, at given conditions in a real world situation, the most important factor is the amount of odorants that are present in the respective liquid. As the amount of odorants that are present in different wastewaters dominantly affects the emission rate, it is necessary to measure this amount of odorants. Thus, the methodology of the Odour Emission Capacity (OEC) was developed to provide a tool for objective characterization of different liquids concerning their property of being odorous. The OEC method was presented by Frechen and Köster (1998). The definition is:

> "The Odour Emission Capacity OEC of a liquid is the total amount of odorants, expressed in ou_E/m^3_{Liquid}, which can be stripped from 1 cubic meter of the liquid under given, standardized conditions."

Figure 2 shows the test reactor for performance of the odour stripping and a sample evaluation of two different tests. The gas samples collected at the off gas outlet of the test reactor are analysed concerning their odour concentration (in air) according to EN 13725:2003 (2003). Basically, the OEC is the integral under the measurement curve of the results of the olfactometric measurements made with the air samples.

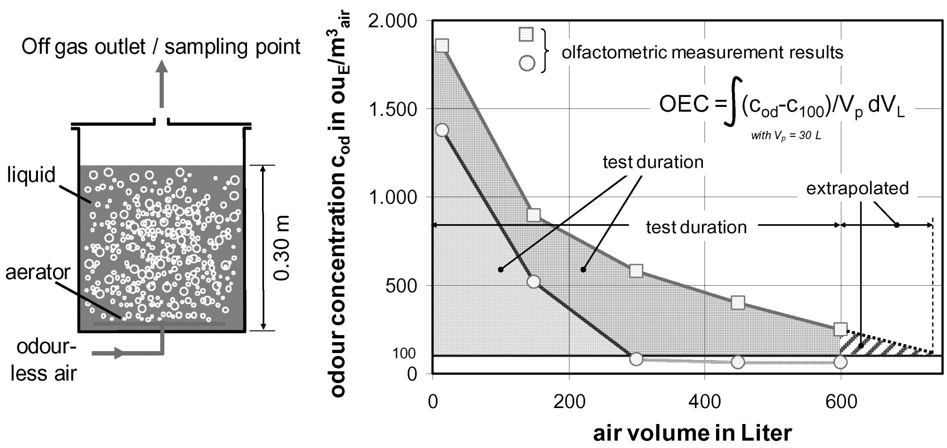

Figure 1. Left: Sketch of stripping test reactor. Right: Sample evaluation of the results of two tests.

The OEC method opens several new ways of dealing with odour problems from sewer systems and allows for a broad range of applications that are explained hereafter.

2.2.2 OEC results of Domestic Wastewaters

In order to give an impression on typical values of the OEC in different liquids, some results of measurements made by DESEE so far should be presented.

Sewage was measured in several sewer systems with different boundary conditions. Up to now, more than 100 OEC measurement results were made, showing an average value of about 90,000 ou_E/m^3_{Liquid}. The range, defined by $\pm \sigma$, is from 4,000 ou_E/m^3_{Liquid} to 400,000 ou_E/m^3_{Liquid}. It must be kept in mind that they result from cases where annoyance was severe as well as from cases where no problems were reported.

During our measurements so far we came to the conclusion that a moderate odour load of a domestic wastewater will be in the range of 20,000 ou_E/m^3_{Liquid} and that, as a basic number under usual conditions concerning neighbourhood of the sewer, a value of 50,000 ou_E/m^3_{Liquid} should not be exceeded. Assessing the above average value under this conclusion, it can be seen that most of the cases where DESEE was to measure the OEC were cases where problems concerning odour emissions already existed. Results of industrial wastewaters are given below.

3. Possible Countermeasures and their Efficiency

3.1 Limitation of highly odorous industrial discharges into the sewer

Depending upon the situation, industrial wastewaters discharged into the public sewer system can cause severe problems. Samples taken at some different enterprises gave the following results:

- Brewery: up to 3,000,000 ou_E/m^3_{Liquid}
- Chemical industry: up to 12,000,000 ou_E/m^3_{Liquid}
- Tannery: up to 15,000,000 ou_E/m^3_{Liquid}
- Meat industry: up to 5,000,000 ou_E/m^3_{Liquid}
- Yeast industry: up to 40,000,000 ou_E/m^3_{Liquid}

Comparing these results with the above mentioned typical value for a domestic sewage without special problems – which are dealt with later in this paper – it can be established that the contribution of industrial discharges in some cases can be predominant even if flow is much less than flow in the sewer. Concerning odorants flow, in the case of the yeast industry wastewater, 1 m^3 of yeast wastewater may contain as much odorants as 2,000 m^3 of domestic wastewater. This clearly indicates the origin of problems.

The most promising countermeasure in these cases is to prevent the industry from discharging liquids with these high OEC values into the public sewer system without appropriate pre-treatment by means of fixing a standard for the maximum allowed OEC of wastewater to be discharged into the sewer. Of course, the OEC measurement method is suited to check for compliance with these standards.

3.2 Dosing of Nitrate

Hydrogen sulphide as one very important odorant is formed in an anaerobic environment which can easily be achieved due to unfavourable conditions in the sewer for several reasons like low speed, flat gradient of the sewer, wastewater with high oxygen demand, biofilm formation in sewers and others, see e.g. Hvitved-Jacobsen and Vollertsen (2001). In these cases it may be efficient to add oxygen to the sewage to prevent it from becoming septic. The addition of nitrate as an oxygen source has in many cases proven to be the most favourable solution.

Insufficient dosing is easy to detect, as the problem is not solved. Operators usually tend to overdose nitrate according to "be safe" and "much helps much". However this can cause a lot of extra cost that is unnecessary and thus is wasted money. Using the OEC for proof of efficiency, i.e. measuring before and after nitrate dosage, reveals whether the dosing is correct. This is the only possibility so far to assess efficiency of dosing as well as economically optimal dosing strategy. This was demonstrated in a R&D project at the sewer system of the city of Cologne. Figure 4 shows some sample results.

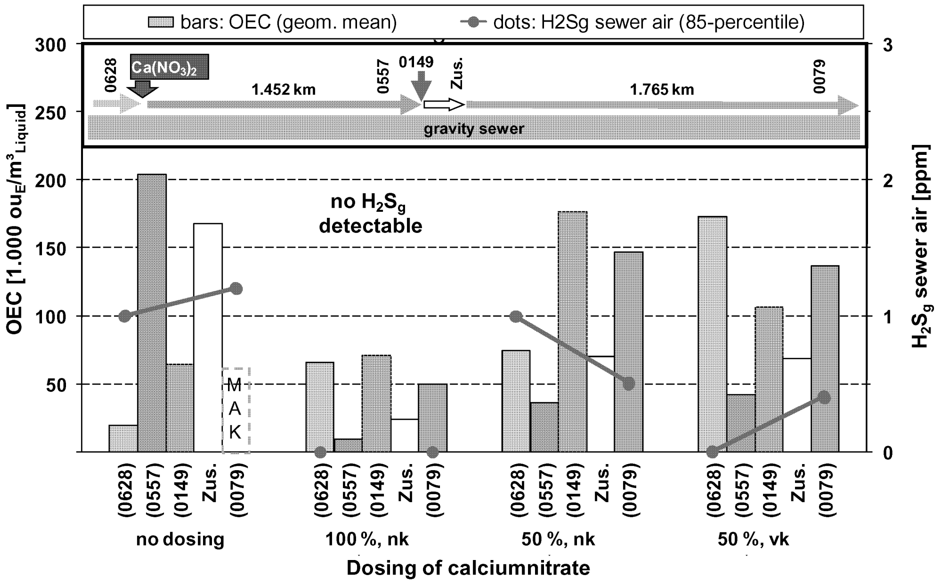

Figure 4. Dosing of calciumnitrate in a gravity sewer: development of OEC in the wastewater and hydrogen sulphide in the sewer air.

Without dosing, the OEC increased from 20,000 ou_E/m^3_{Liquid} at the beginning of the sewer at manhole (0628) to more than 200,000 ou_E/m^3_{Liquid} at manhole (0557) 1.452 km downstream. Dosing of calciumnitrate with dosing strategy "100%" revealed that the OEC at the same part of the sewer was reduced from 70,000 ou_E/m^3_{Liquid} at manhole (0628) down to 10,000 ou_E/m^3_{Liquid} at manhole (0557). Even another 1.765 km downstream and after an additional load introduced at manhole (0149), the OEC did not exceed 50,000 ou_E/m^3_{Liquid}, Reducing the dosing strategy to 50% still resulted in a reduction of the OEC at manhole (0557), but in the sewer segment downstream to manhole (0079), an increase was measured.

3.3 Pressure mains, dosing of iron salts, hydrogen peroxide

In a second research project at part of the sewer network of the city of Mönchengladbach, a short test was conducted during the operation of a pressure main with a subsequent gravity sewer. The results are shown in Figure 5.

Without dosing, the OEC at the beginning of the pressure main was 65,000 ou_E/m^3_{Liquid} and increased until reaching the end of the pressure main after 2.2 km to an average value of about 3,700,000 ou_E/m^3_{Liquid} which is typical for pressure mains. Decrease of OEC during the subsequent gravity sewer with length of 2.3 km plus 1.9 km = 4.2 km is attributed to the high OEC and thus emissions from the gravity sewer.

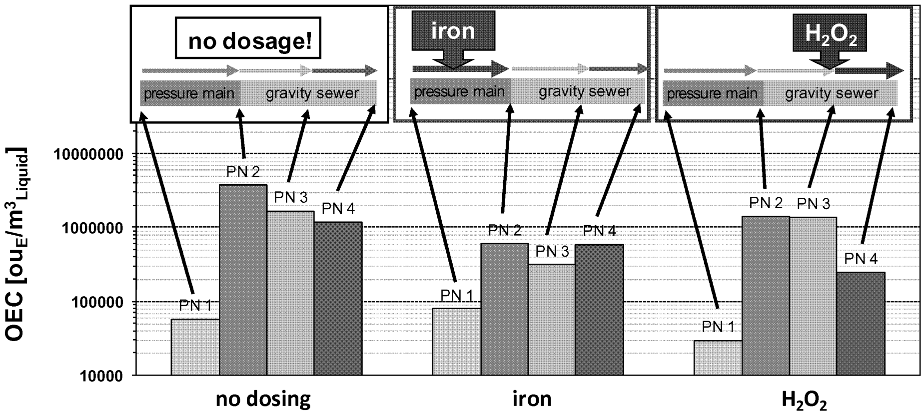

Figure 5. Dosing of iron salts and hydrogen peroxide after a pressure main.

In the second test phase, iron salts were dosed at the beginning of the pressure main. As can be seen, still a rise of OEC from 80,000 ou_E/m^3_{Liquid} at the beginning of the pressure main up to 600,000 ou_E/m^3_{Liquid} at the end was observed. This indicates that the dosing was partly efficient and should be increased.

During the third test phase, hydrogen peroxide was dosed into the gravity sewer after 2.3 km of run length. By this the OEC decreased from 1,400,000 ou_E/m^3_{Liquid} at the dosing station down to 250,000 ou_E/m^3_{Liquid} after another travel of 1.9 km until point PN4. Thus, also dosing of hydrogen peroxide proved to be efficient.

The final recommendation was to combine the two measures and to increase the iron salt dosage to enhance the effect of the whole measure. However, it must again be stated here that these recommendations were only possible due to the OEC measurement.

4. Emscher Sewer

4.1 Short overview over the project

The Rhine-Ruhr-area, Germany's most populated and industrialized area with some 3 million inhabitants, mainly is still dewatered via the small river Emscher that since 100 years served as an open sewer. In the 80ties, it was decided to change this situation. The responsible body Emschergenossenschaft had/has to erect three new large wwtps, construct the emscher sewer and renature the river Emscher, see Teichgräber et al. (2005). Total cost of this project which is expected to be finished around 2012, exceeds 4.5 billion €. Main data of the emscher sewer, of which most has to be build yet, are:

• Length:	51 km
• Depth:	8 m to 40 m
• No pumping stations:	3
• Diameter:	up to 2 x 2,800 mm
• Manholes:	130
• Manhole diameter:	12 m

This sewer will be equipped with ventilation, where at over 30 manholes odour abatement units have to be installed. DESEE is commissioned to design the waste air treatment concept. It is evident as of today that chemical dosing will be necessary in order to reduce odour generation in the sewer and to protect the sewer from concrete corrosion. Hereafter, two special aspects in conjunction with this project will be considered.

4.2 Connecting the existing sewer networks to the new sewer

Most of the existing city-owned sewer networks of the Rhine-Ruhr-area have to be connected to the new emscher sewer. Due to the difference in depth of the two elements there are several drops necessary to realize this connection. As mentioned before, points of high turbulence such as drops cause odour emissions, if odorants are present. In this case, a prognosis was needed concerning the amount of odorants that are emitted due to the drops, as the waste air of the drops carrying the odour load has to be treated in deodorization plants.

Obviously, the percentage of odorants emitted from the wastewater increases with the height of the drop. Thus, DESEE carried out tests at drops of different height in order to determine these emissions. Determination of the amount of odorants set free during drop needed the OEC measurement method as a tool, where different wastewaters were measured concerning their OEC before being dropped, and after being dropped over different heights.

The emission then can be estimated as the OEC difference before and after a drop. In addition, of course, it is necessary to know the OEC of the wastewater that will be dropped. This had to be done by measuring the OEC of different wastewaters that can be found in the respective area. Combining the information, it was possible to estimate an odour emission rate for every drop in the system that will be in operation in the future, and design the necessary waste air deodorization plants.

4.3 Dosing process control for the new emscher sewer

As pointed out above, the OEC method is suited to determine whether the dosing strategy employed is effective and cost-saving, preventing from overdosing costly chemicals. However, as the OEC measurement described so far is an off line method, DESEE developed an automated version of the method. This brought up the need for a sensor that will be able to replace the human nose, also called “electronic nose”.We choose two different types of electronic noses (semiconductor based and quartz-oscillating based) for research and test purposes. These works are still ongoing.

The second challenge was to create the automated device that would be able to do the OEC test continuously in cycle operation mode. Figure 6 shows the pilot device that was built by DESEE. The design includes two test reactors, where one reactor is used for OEC measurement and the other is used for analyzing the sulphide concentration of the liquid, which includes automatic pH reduction to below a value of 4 according to the DIN 38405-27 method. Thus, the whole unit delivers an OEC value and a sulphide concentration roughly every 10 minutes.

Two devices built based on the experience with the pilot unit are in operation in the Emscher area since spring 2007. The respective R&D project runs until 2009.

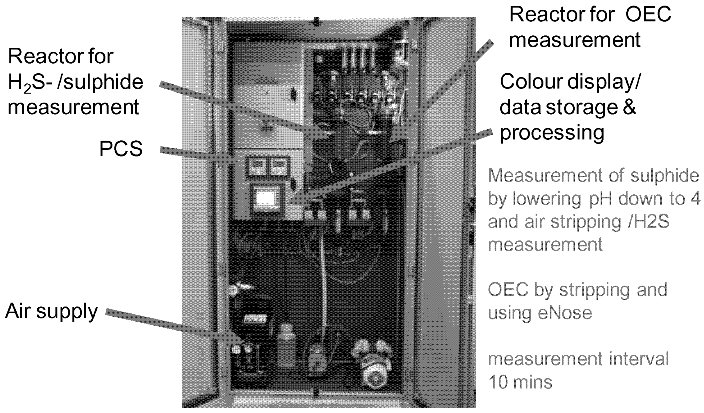

Figure 6. Automated analyzing unit for nearly-online OEC and sulphide concentration measurement

5. Conclusions

The work of the last 10 years on the OEC method and its applications has shown that this method is inevitable to get objective results concerning the relevance of liquids concerning odours. Thus, in the future the OEC as a (waste)water parameter will be of rapidly increasing interest as the method helps with many important applications. More information on recent R&D work is available at www.uni-kassel.de/fb14/siwawi.

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