

Odour Abatement of Waste Gases from Sludge Thickeners in Wastewater Treatment Plant Using Bioscrubber

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The research objective was to determine odour abatement efficiency of waste gases from sludge thickeners with the use of bioscrubbers. Olfactometric measurements were performed in the large mechanical-biological wastewater treatment plant in one of the biggest cities in Poland. The installation assessed was the 3-stage British system comprised of two identical bioscrubbers from lava rock media at the beginning, and dry chemical scrubber at the end.

A three-day measuring session was conducted in October 2012. Nine observations of the relative difference in odour concentration in the crude and clean gas stream in determined conditions were carried out in each stage. In total, 36 samples were taken - 9 samples for each of the four measuring points. The lung principle method was used for sampling. Parameters necessary to calculate the odour flow rate, such as gas temperature, absolute pressure or volume flow rate were measured using the TESTO 400 meter. The samples were transported to the Olfactometric Mobile Laboratory of the Laboratory for Odour Quality of the Air, located ca. 6 km from the object of study. Odour concentration was measured using the Ecoma TO7 dynamic olfactometer and the experienced panel that met the selection criteria of the EN 13725 standard for the olfactory sensitivity. The quality parameters determined in the Interlaboratory Comparison of Olfactometry 2012 for 1-butanol in nitrogen, were: precision $r = 0.453$ and accuracy $A_{od} = 0.234$.

The results confirmed the high odour abatement efficiency of over 90 % for the first bioscrubber, with the odour flow rate order of magnitude of 100,000 ou_E/s in the crude stream as well as the second bioscrubber where the odour flow rate order of magnitude was below 9,000 ou_E/s. The effectiveness of the use of the two series-connected bioscrubbers exceeded 99% and the overall effectiveness of the three-stage installation equalled 100 %.

1. Introduction

The odour abatement is an end-of-pipe method that should be applied only if all options to prevent odor nuisance, such as reasonable location of a plant or height of the emitter have been used and is based on the following:

- removal of volatile compounds with a characteristic odour and low odour detection threshold (compounds recognized as potentially responsible for odour of multicomponent mixture of waste gases)
- turning the aforementioned compounds into odourless compounds or compounds with a higher odour detection threshold
- implementing compounds causing change of odour nature or reducing the intensity of an olfactory sensation, e.g. masking agent (Lazarova et al, 2012)

There is a variety of odour abatement methods and their applications (Kennes and Veiga, 2010; Pillai et al., 2012). The choice of a deodorization method is highly dependent upon investment and operating costs as well as odour abatement efficiency required. However, the difficulty lies in the fact that the information

about the olfactometrical effectiveness of various technologies determined in accordance with the EN 13725 in real conditions, is not easy to be found in the literature.

The odour abatement efficiency is influenced by factors, such as volume flow rate, physicochemical parameters and pollution level of the cleaned gas. Nevertheless, high odour abatement efficiency is difficult to achieve due to scarce amounts of compounds with low odour detection threshold that are found in waste gases (the concentration of these compounds is often undetectable by analytical methods) (Almarcha et al., 2012). This paper presents the evaluation of the effectiveness of odour abatement of waste gases from biodegradation processes using bioscrubbers. The efficiency was evaluated according to the EN 13725 standard (EN 13725, CEN, 2003), with the measuring session having been conducted on a large scale in real conditions in October 2012.

2. Object of study

The tests were performed in the mechanical-biological wastewater treatment plant of the capacity of 50,000 m³/d. The WWTP was built at the beginning of the 20th century in the rural area north to the existing at that time city, and absorbed by the developing city over time. Nowadays, there are more and more residential buildings in the neighbourhood of the WWTP, which is the reason why elimination of odour nuisance is a big challenge, which raises the need for effective odour abatement installation.

2.1 Source of odorous gases

Two tanks of primary sludge hydrolysis (to which the sludge from the initial settling tank is directed) and mixing tank of thickened sludge (primary sludge and excess sludge) were the main source of odour emissions. The total volume of odorous air equalled 1,100 m³/h. The crude gas temperature ranged between 10 – 25 °C, with gas humidity exceeding 70 %. Chemical analysis by FTIR and GC/MS showed numerous components that included hydrogen sulfide, dimethyl sulfide, dimethyl disulfide, toluene, limonene and mercaptans in the crude gas stream. The regular measurements using the Dräger tubes showed that concentration of ammonia and mercaptans were lower than 10 ppm, while hydrogen sulfide concentration exceeded at times 100 ppm. The odour concentration measurements carried out in accordance with the EN 13725 standard at different times showed differences between 50,000 ou_E/m³ and 250,000 ou_E/m³ in the crude gas stream.

The originally applied installation (i.e. biofilter with humidification chamber operated by the experienced staff in accordance with the supplier's guidelines) turned out to be insufficient due to the close proximity to residential areas (ca. 30 m from the WWTP). It was thus necessary to apply another odour removal technology that reduced odour concentration to 1,000 ou_E/m³.

2.2 Odour removal installation

The comprehensive review of odour abatement technologies applied worldwide was conducted, and decision made based on costs optimization. The technology selected is a combination of three systems: water scrubber, biofiltration and chemical sorption. The scheme of the installation is presented in Figure 1. Similar systems are functioning successfully in the British WWTP.

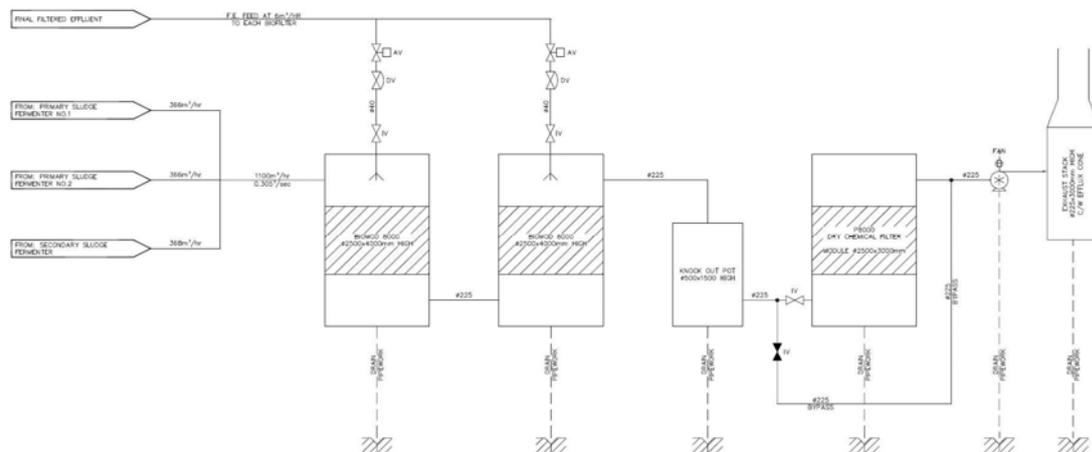


Figure 1: Scheme of the odour removal installation



Figure 2: Odour removal installation tested

The installation consists of three tanks connected in series (Figure 2), each of which is filled with the purifying air medium. The first two first tanks are identical (bioscrubbers) and filled with lava rock, constantly wetted with purified wastewater. This gives the following advantages:

1. filter has a large surface of biofilm owing to the large surface area of the volcanic material
2. wetting with treated wastewater guarantees supply of nutrients to the biofilm
3. the use of the mineral medium (i.e. volcanic material) guarantees a long life of the filter and eliminates secondary odour emissions from the organic matter decomposition

After stage two, treated gases are directed to the droplet eliminator, and then to the third tank. The third tank (dry chemical filter scrubber) contains a combination of an iron oxide, stabilized chlorine dioxide and active carbon. Pollutions not removed in previous stages are reduced in stage three.

3. Materials and methods

3.1 Sampling

The samples for the olfactometric analysis were taken at four points: 1 – before the first bioscrubber, 2 – after the first bioscrubber and before the second bioscrubber, 3 – after the second bioscrubber and before dry chemical scrubber, 4 – after dry chemical scrubber. The samples were collected in the bags made of polyethyleneterephthalate (NalophanTM) using the lung principle method. The two identical *UPP-2* of *LAT* sampling systems were applied in sampling. Four sampling teflon lines of the length of 2 m were used (a separate probe for each sampling point) as well as a new bag was used every time (conditioning bags were skipped). A set of samples for a single observation of the odour removal efficiency of the 3-stage treatment unit was taken from the first to the fourth sampling point as shown in Figure 3. Bag replacement dislocation of the sampling system took place during pauses (P) as shown in Figure 3. Sampling time of four bags ranged between 38 and 67 minutes for the first two observations (sampling time of one bag lasted 10 minutes; collected gas volume about 15 dm³) or between 17 and 31 minutes in other cases (sampling time of one bag lasted 6 minutes; collected gas volume about 8 dm³). In total, 36 samples were taken (nine from each sampling point). Parameters necessary to calculate the odour flow rate, such as gas temperature, absolute pressure or volume flow rate were measured using the TESTO 400 meter at all sampling points for each observation.

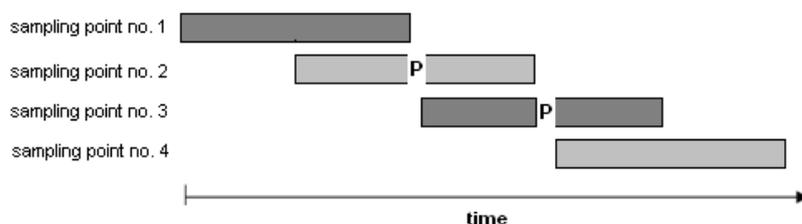


Figure 3: Sampling sequence of odour removal efficiency of the 3-stage treatment unit

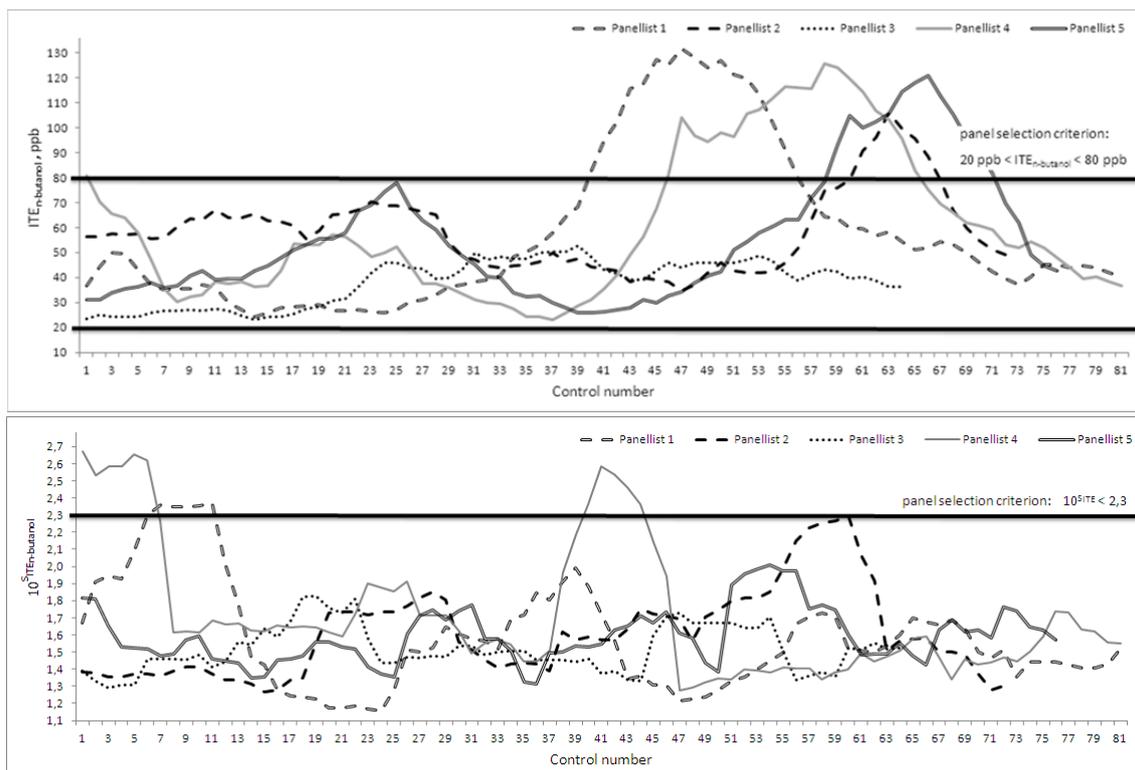


Figure 4: Control history of individual threshold estimate for *n*-butanol: $ITE_{n\text{-butanol}}$ (the geometric mean of 10 last measurements) of assessors (above) and the antilog of the standard deviation S_{ITE} control calculated using the logarithms (\log_{10}) of the $ITE_{n\text{-butanol}}$ (below)

3.2 Odour determination

The measurements of odour concentration were conducted according to the EN 13725: 2003 standard by the odour panel, whose members had been controlled for a period of time. The history of olfactory sensitivity of the assessors participating in the measurements juxtaposed with the standards is presented in Figure 4.

The olfactometric measurements of the odour concentration c_{od} [ou_E/m^3] were conducted in the Olfactometric Mobile Laboratory of the Laboratory for Odour Quality of the Air (Figure 5a). The conditions, such as temperature, humidity and CO_2 concentration in the laboratory were controlled at all times. The laboratory was installed beyond the odour impact. The time between the sampling and the olfactometric analysis ranged from 1 to 7,5 hours. The samples were analyzed in fours – from the least concentrated (sampling point no. 4) to the most concentrated (sampling point no.1). Odour concentration was measured using the Ecoma TO7 dynamic olfactometer (Figure 5b). The following was applied when necessary:

- in 31 out of 36 samples - a hundredfold pre-dilution (function of TO7),
- in 20 out of 36 samples - a pre-dilution of the sample with the use of the glass syringe shown in Figure 5c (a volume of clean air was measured in the bag and then odorous gas was added into it).

A YES/NO mode was used in the measurements. A decreasing geometric sequence with the common ratio 2, created by the consecutive Z values was presented to the odour panel. A sequence of decreasing dilutions was disturbed by the presentation of random blanks. During the measurements, the presentation of a dilution series to the odour panel was repeated three times. At least two measurements were performed for each sample, with 8 to 16 samples analyzed per day. The total number of analyses conducted was 75. According to the EN-13725 standard, correspondence of the results with the screening panel criterion was tested and ca. 2.7 % results were rejected upon verification. The calibration on curves of the olfactometer (the same as in the Interlaboratory Comparison for Olfactometry 2012) was included in the calculation of c_{od} . The overall quality of the sensory measurement of odour concentrations in the laboratory assessed by ILC for Olfactometry 2012 was as follows: precision $r = 0.453$ and accuracy $A_{od} = 0.234$.

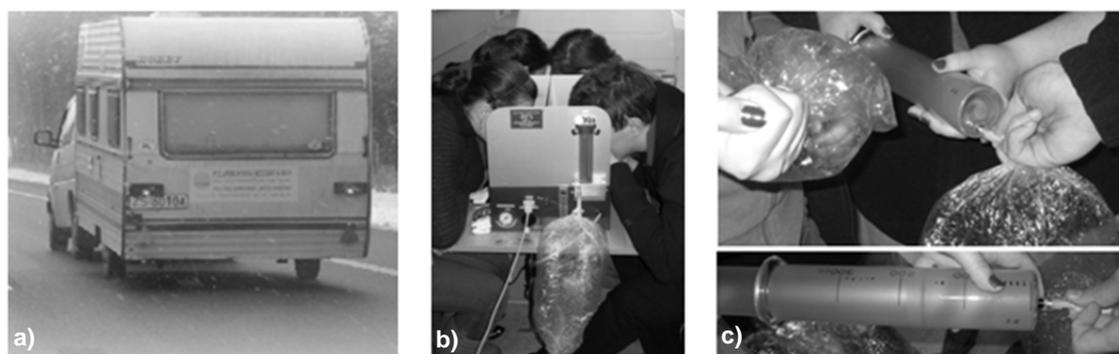


Figure 5: Odour concentration determination
a) the mobile laboratory, b) the Olfactometer TO7, c) a pre-dilution before olfactometric analysis

3.3 Determination of odour abatement efficiency

The odour abatement efficiency (η_{od} [%]) was calculated as an average of nine observation of the relative difference in odour concentration in the crude and clean gas stream. The odour flow rate q_{od} [ouE/s] was calculated as the product of odour concentration and volume flow rate (the measured value). All calculations were performed according to the EN 13725 standard. The 95 % confidence interval for the abatement efficiency was estimated using the volume of the standard deviation of differences ($s_D = 0,2311$) for the precision $r = 0.453$, determined in the ILC for Olfactometry 2012.

4. Results and discussion

Table 1 presents the results of the odour flow rate determination at each sampling point. Figure 6 shows the results of the assessment of odour abatement efficiency in the 3-stage installation.

The results confirmed the odour abatement efficiency of over 90 % at each stage of treatment. The 3-stage odour abatement system reduced the odour concentration of waste gases from sludge thickeners to the level of several tens or hundreds of the European odour unit per cubic metre. It is worth mentioning that almost 100 % odour removal efficiency was achieved at the second treatment stage. The conclusion might therefore be that a 2-stage system can be enough to solve the problem of odour nuisance. To verify whether reduction of odour emission to the level of several hundreds of the European odour unit per second is enough, odour dispersion modeling has to be carried out.

Table 1: Odour flow rate at sampling points

Observation	Odour flow rate, q_{od} [ouE/s]			
	Sampling point 1	Sampling point 2	Sampling point 3	Sampling point 4
1	82,704	4,155	249	3
2	72,303	1,880	229	7
3	156,909	6,861	323	12
4	50,089	2,079	30	9
5	249,842	9,483	281	20
6	136,981	13,002	1,682	163
7	70,682	13,107	2,696	144
8	194,919	11,870	743	148
9	28,191	15,844	401	30
Mean value	94,907	6,865	390	25
95 % confidence interval for results	74,220	5,368	305	20
	121,358	8,778	498	32

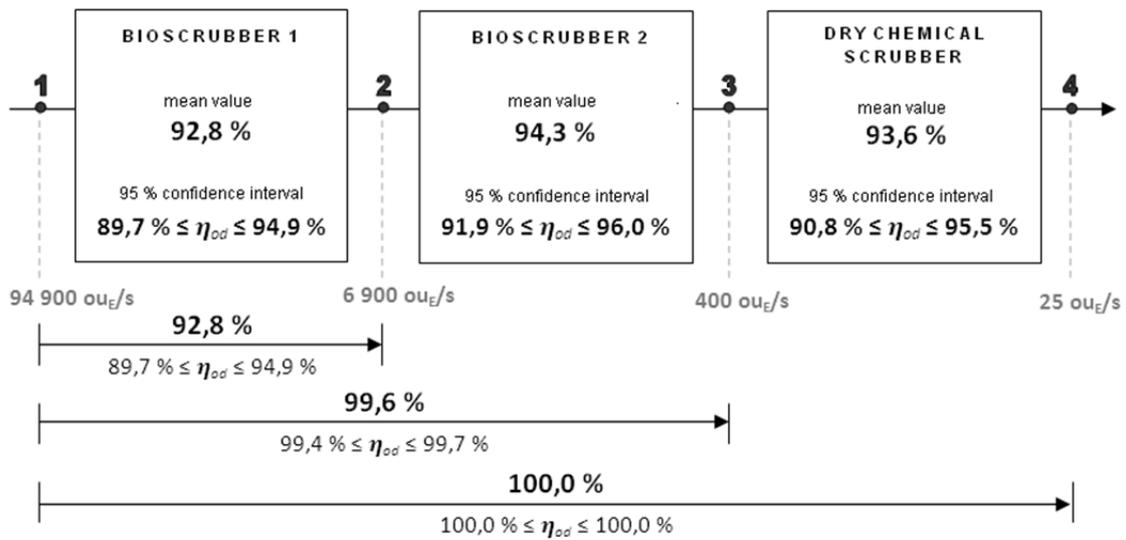


Figure 6: Odour abatement efficiency of the 3-stage installation

5. Conclusions

The application of bioscrubbers can be considered to be an effective solution to reduce odour emission from biodegradation processes. The over 90 % odour abatement efficiency was confirmed for the crude stream with the level of pollution differences between several hundred and 100,000 ou_E/s.

References

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