Odour emission from primary settling tanks after air-tightening

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The purpose of the present article was to determine odour emission rate from primary settling tanks after hermetisation. The paper presents the results of the research on odour emission from four settling tanks, covered with self-supporting aluminium domes with a diameter of 52 meters, located on urban wastewater treatment plants, with the planned flow capacity equal to 200 000 m³/day. Altogether, the olfactometry analysis of 189 samples of polluted air pulled from the domes with the use of an air blower which has efficiency of 12 000 m³/h was conducted. The results of odour concentration measurements were in a range of approximately 10 800 to 763 600 ouE/m³. Average odour emission rate was equal to 102 ouE/(s · m²). The obtained value is much higher than the literature data, available for non-hermetised settlers only. This rate enables better estimation of the odour stream that has to be deodorised after sealing the settling tanks.

**Keywords:** odour emission, odour emission rate, air tightening, primary settling tank, wastewater treatment plant.

**INTRODUCTION**

Nowadays, technologies and installations that have the least possible impact on the environment are desirable1–2. One of the most onerous impacts is odorous impact3–7. Odour nuisance can be counteracted in various ways, such as: change of type of resources or technologies, modification of process parameters, increase of ejection point of polluted air to the atmosphere, hermetisation, deodorisation and also – in the case of new objects – proper localization8–18. The choice of the optimal solution is possible by modelling odorants dispersion. As a result of such calculations, the olfactory range of the installation impact can be estimated for the subject matter in question19–23. However, the use of deodorisation with a certain odour abatement efficiency is frequently the only possible solution.

There are various methods of deodorisation. The choice of the right one depends strictly on the parameters of the air stream to be treated, such as: volume flow, temperature, humidity or pollutant charge, as well as expected odour concentration reduction level24. In order to design a suitable deodorising installation, knowledge of the odour concentration in the treated stream is needed. This quantity can be estimated in two ways: by performing olfactometric measurements at the source of emission, or by using literature data – odour emission rates25–29. However, there are facilities, such as primary settling tanks that are a dominant source of odour nuisance generated by wastewater treatment plants, where determination of odour emission is problematic30–34.

The primary settling tanks are the last stage of the mechanical wastewater treatment and are large, usually round or rectangular tanks with proper instrumentation, where sewage flows through. Their task is to remove easily falling suspensions (as a result of sedimentation) as well as suspensions lighter than water, which flow to the surface.

The primary settling tanks are diffusion sources, characterized by large surface and unorganized variance of pollutions. The size of this emission depends on numerous factors, such as: composition of wastewater, their turbulence, pH, temperature, size of mass exchange area (liquid – gas), and wind velocity over this surface35–37. Therefore, taking representative samples for olfactometric analysis is problematic38–41. The methodology for collecting samples to determine odour emission from surface sources is still not standardised. In practice, wind tunnels or shields are used to cover section of sewage surface, enforcing flow of known size underneath them (see Fig. 1). Samples of polluted air are taken at the outlet from the tunnel/shield, in a similar way as organised emission. Construction of tunnels and shields is varied, which can significantly affect the measurement results39.

![Figure 1. Principle of sampling on a passive surface source](image-url)

Literature data on odour emissions from primary settling tanks are few and far between. In 2004 Frechen published odour emission rates from primary settling tanks, relating to one m³ of sewage area, at the level of 0.64 ouE/s, and for weir – 2.14 ouE/s (see Table 1)42. In 2015 Sówka, Sobczyński and Miller presented the results of odour emission measurements from the primary settler obtained in selected months, ranging from 30.9 ouE/(s · m²) to 72.9 ouE/(s · m²) (see Table 2)43. In turn, the Sobczyński, Sówka and Bezyk publication (also from 2015) presents 14 results of odour emission measurements from the primary settling tank (see Table 3), carried out in the period from October to February, whose average
value, related to 1 m² of the sewage area, is 22,8 \( \text{ouE} / (s \cdot m^2) \) and the minimum and maximum values of 7,9 \( \text{ouE} / (s \cdot m^2) \) and 68.5 \( \text{ouE} / (s \cdot m^2) \) respectively.

Differences in the above mentioned values of the odour emission rates from the primary settling tanks may have a significant impact on the values determined with their use. As a result, this may lead to an incorrect estimation of the odour impact range of the primary settling tanks or the size of the odour flow rate after settlers have been sealed air tight. The literature on the subject is missing information on odour emission from primary settling tanks after hermetization. In this work, the rate of odour emission from hermetized primary settling tank was estimated on the basis of a large set of results of olfactometric measurements conducted under real conditions.

**OBJECT OF STUDY**

The research was carried out on a mechanical – biological municipal wastewater treatment plant with an increased degree of biogen removal and full processing of sewage sludge. This treatment plant treats wastewater from both households and industrial plants (e.g. food industry, pharmaceutical industry, automotive industry, cosmetics industry, printing industry and chemical industry). Its designed capacity is 200 000 m³/d. Four identical horizontal flow radial settlers with chain scrapers were tested (see Fig. 2). The technical parameters of each of the settling tanks are presented in Table 4.

**RESEARCH METHODOLOGY**

Measurements of odour emission from the settling tanks were carried out after their air tightening with the use of a „solid – self supporting” aluminium cover (see Fig. 3). The flow of the ventilation air from each of the settling tanks was 12 000 m³/h. The measurements were carried out over a period of 6 years, starting in 2014, when the first two covers were installed. A total of 6 measurement sessions were conducted, one each in February (2015), and October (2017) and three each in September (2014, 2018 and 2019). The measurement sessions lasted from 2 to 4 days, depending on the number of settling tanks tested (see Table 5). Only one settling tanks was

![Figure 2. Primary settling tanks before hermetization](image1)

![Figure 3. Primary settling tanks after hermetization](image2)
assessed every day. Nine ventilation air samples were taken from each settling tank. Samples were taken at different times of the day, on average every 1.5 hours.

Between subsequent observations, atmospheric conditions were monitored with the use of T esto 400 meter and appropriate probes. Table 5 summarises the sampling atmospheric conditions, the average value (a) of the atmospheric pressure, temperature, humidity, and their lowest (l) and highest (m) values.

The „lung“ method without pre-dilution was used for sampling. The sampling system consisted of a rigid container, in which the bag was placed, a control system producing a vacuum in the container and a probe in the form of a teflon tube with an inside diameter of 4 mm (see Fig. 4). Two probes were used alternately for each measuring point. Each probe was flushed with clean air before the next use. Samples were taken continuously for about 10÷20 minutes at a speed of about 50÷100 l/h. Each sample was taken into a new bag made of Nalophan film and a teflon tube with a stopper.

![Figure 4. Sampling for the determination of odour concentration](image)

Immediately after sampling, the samples were transported to the Mobile Olfactometric Laboratory, installed about 2 km from the research facility, where the olfactometric analysis was performed. During the measurements, environmental conditions, such as temperature and CO₂ concentration, in the laboratory were monitored. The determination of odour concentration (cₐₜ [µg/m³]) was carried out using the dynamic dilution method according to the EN 13725:2003 „Air quality – Determination of odour concentration by dynamic olfactometry” using a TO7 (measurement sessions in 2014 and 2015) or TO9 (measurement sessions in 2017, 2018 and 2019) four-panelist station olfactometer. They were attended by an experienced odour panel with olfactory sensitivity to n-butanol controlled in accordance with the EN 13725 (the panelists conducted between several dozen to more than 2000 controls in their measurement history). A total of 18 panelists took part in the study. The yes/no method was used to present samples to the panelists. The samples were pre-diluted before connection to the olfactometer. Two odour concentration determinations were performed for each sample.

The results from all the settling tanks obtained during one measurement session were treated as one set of data, for which the average and 95% confidence interval were calculated. The confidence interval of the measured odour concentration for the measurement session was determined from the relationship:

\[
\bar{y}_w = \bar{y} - t \cdot \frac{s_r}{\sqrt{n}} \leq m \leq \bar{y}_w + t \cdot \frac{s_r}{\sqrt{n}}
\]

where

- \( \bar{y}_w \) – average of the measurement results
- \( m \) – expected value
- \( t \) – Student’s factor for \( n = \infty \) (\( t = 2 \) for 95% confidence interval)
- \( n \) – number of observations (\( n \) depending on the measurement session)
- \( s_r \) – standard deviation for precision measurement determined as a result of the international Proficiency Test of Olfactometry in a given year.

**RESULTS AND DISCUSSION**

The set of results of odour concentration (cₐₜ) measurements in the ventilation air stream of the primary settling tanks after air-tightening, obtained in particular measurement sessions is shown in Fig. 5. The mean value of odour emission (qₐₜmean – geometric mean from n observations in a given measurement session) together with 95% confidence interval of the result obtained for particular measurement sessions is presented in Table 6.

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**Table 5. Characteristics of the measurement sessions**

| Measurement session | D [days] | PS [pcs.] | S [pcs.] | T [°C] | P [hPa] | H [%] |
|---------------------|---------|-----------|----------|--------|---------|------|
|                     | a       | l         | m        | a      | l       | m    |
| 09.2014             | 2       | 2         | 18       | 17     | 13      | 21   |
| 02.2015             | 4       | 4         | 36       | 6      | 0.4     | 10   |
| 05.2015             | 3       | 3         | 27       | 16     | 12      | 20   |
| 10.2017             | 4       | 4         | 36       | 11     | 8       | 20   |
| 09.2018             | 4       | 4         | 36       | 18     | 14      | 24   |
| 09.2019             | 4       | 4         | 36       | 17     | 9       | 24   |

D – length of the measurement session, PS – number of settling tanks tested, S – total number of the samples taken, T – air temperature, P – atmospheric pressure, H – atmospheric humidity, a – mean value, l – minimum value, m – maximum value.
Table 6. Results of the evaluation of the odour emission in individual measurement sessions

| Measurement date | Number of observations (n [pcs.]) | Minimum value (q虞,min) (ouE/s) | Maximum value (q虞,max) (ouE/s) | Mean value (q虞,mean) (ouE/s) | 95% confidence interval |
|------------------|-----------------------------------|-----------------------------|-----------------------------|-----------------------------|------------------------|
| 09.2014          | 18                                | 160 046                     | 637 710                     | 327 595                     | 274 160 – 391 445      |
| 02.2015          | 36                                | 197 735                     | 319 086                     | 246 956                     | 217 739 – 280 093      |
| 05.2015          | 27                                | 92 785                      | 241 616                     | 143 051                     | 123 694 – 165 437      |
| 10.2017          | 36                                | 38 083                      | 210 907                     | 106 828                     | 94 897 – 120 258       |
| 09.2018          | 36                                | 148 534                     | 2 545 213                   | 456 433                     | 403 636 – 516 135      |
| 09.2019          | 36                                | 42 042                      | 724 769                     | 180 682                     | 170 396 – 191 590      |

Table 6 also shows the lowest (q虞,min) and the highest (q虞,max) value of odour emission recorded in particular measurement sessions.

The results obtained confirm high variability of odour concentration in the ventilation air stream of the primary settling tanks after air-tightening. Both the highest values and the highest spread of the results were obtained in September 2018. This may be related to weather conditions and the associated residence time of the wastewater in the settling tanks. The period preceding the session was characterized by low precipitation and relatively high temperatures (see Table 7). In turn, the lowest values were obtained in October 2017, the period with the most rainfall. Therefore, it can be assumed that the more wastewater is diluted by precipitation and stays shorter in settling tanks, the lower the odour emission from the primary settling tanks. In addition, it can be noted that the higher the temperature of the atmospheric air, the greater the variation in odour concentration in the air discharged from the settling tanks. However, determination of this relationship is a separate research topic.

Table 7. Characteristics of atmospheric conditions for the week and month preceding a given measurement session

| Measurement date | Average air temperature [°C] | Total rainfall [mm] | Odour emission rate [ouE/(s · m²)] |
|------------------|-----------------------------|-------------------|----------------------------------|
|                  | weekly | monthly | Total | weekly | monthly | Mean | 95% confidence interval |
| 09.2014          | 12.5   | 15.6    | 8.9   | 43.5   |         | 154  | 129 – 184               |
| 02.2015          | 1.8    | 0.5     | 0.0   | 17.7   |         | 116  | 103 – 132               |
| 05.2015          | 12.5   | 12.1    | 4.1   | 28.8   |         | 67   | 58 – 78                 |
| 10.2017          | 10.9   | 12.0    | 17.6  | 51.7   |         | 50   | 45 – 57                 |
| 09.2018          | 17.2   | 18.7    | 4.9   | 13     |         | 215  | 190 – 243               |
| 09.2019          | 13.7   | 18.3    | 3.8   | 41.7   |         | 85   | 80 – 90                 |

Figure 5. Distribution of odour concentration measurement results obtained in individual measurement sessions.

Table 7 shows the average values of odour emission rates from the primary settling tank after air-tightening (together with the 95% confidence interval of the result), calculated for individual measurement sessions. These ratios are expressed in odour units per second and related to 1 m² of sewage area. The average value of the rate for the whole set of data collected during six measurement sessions (total of 189 values) was 102 ouE/(s · m²). The rate corresponding to the highest recorded value of the odour concentration in this set is 1200 ouE/(s · m²). The values obtained differ significantly from the literature data24, 42, 43, determined on the basis of studies carried out in open primary settling tanks (without air-tightening). It is therefore confirmed that for the determination of odour emissions from large surface sources (such as settling tanks), the method of sampling for olfactometric analysis is important. Therefore, the rates determined for this source before air-tightening cannot be used to estimate the size of the polluted odour stream, emitted from the primary settling tanks after air-tightening. It is necessary to apply the rate relating to air-tightened settling tanks.

Table 8. Odour emission rates from the primary settling tanks after air-tightening

CONCLUSIONS

Primary settling tanks are an important source of odour nuisance at wastewater treatment plants. One of the ways to reduce this nuisance is hermetization of the settling tanks and deodorization of the ventilation air. When estimating the amount of pollutants in the air to be treated, rates related to the settling tanks after air-tightening should be used. Using the values set for open tanks, the projected emissions may be significantly underestimated in relation to the actual ones, and this may result in an inefficient installation of the air purification plant of the air discharged from the settling tanks. The average odour emission rate of the primary settling tanks after air-tightening is 102 ouE/(s · m²). The minimum value recorded during the tests is 17 ouE/(s · m²) and the maximum one is 1200 ouE/(s · m²). Higher values and higher variability of emissions were observed in the case of measurement sessions characterized by lower precipitation and higher temperatures.
33. Sówka, I., Grzelka, A. & Miller, U. (2017). Problematyka odorów w procesach gospodarki ściekowej. Wodociągi-Kanalizacja. 6(160), 39–42.

34. Capelli, L., Sironi, S., & Rosso, R.D. (2014). Odour Emission Factors: Fundamental Tools for Air Quality Management. Chem. Engin. Transac., 40, 193–198. DOI: 10.3303/CET1440033.

35. Hudson, N. & Ayoko, G.A. (2008). Odour sampling 1: Physical chemistry considerations. Biores. Technol., 99(10), 3982–3992. DOI: 10.1016/j.biortech.2007.04.034.

36. Nagaraj, A. & Sattler, M. (2005). Correlating Emissions with time and temperature to predict worstcase emissions from open liquid area sources. J. Air & Waste Manag. Assoc., 55(8), 1077–1084. DOI: 10.1080/10473289.2005.10464713.

37. Schwarzenbach, R., Gschwend, P. & Imboden, D. (2003). Environ. Organic Chem., 2nd Edition. New York: John Wiley & Sons.

38. Capelli, L., Sironi, S., Del Rosso, R., & Céntola, P. (2009). Design and validation of a wind tunnel system for odour sampling on liquid area sources. Water Sci. Technol., 59(8), 1611–1620. DOI: 10.2166/wst.2009.123.

39. Hudson, N. & Ayoko, G.A. (2008). Odour sampling. 2. Comparison of physical and aerodynamic characteristics of sampling devices: A review. Biores. Technol., 99(10), 3993–4007. DOI: 10.1016/j.biortech.2007.03.043.

40. Hudson, N., Ayoko, G.A., Dunlop, M., Duperouzel, D., Burrell, D., Bell, K. & Heinrich, N. (2009). Comparison of odour emission rates measured from various sources using two sampling devices. Biores. Technol., 100(1), 118–124. DOI: 10.1016/j.biortech.2008.05.043.

41. Hudson, N., Bell, K., McGahan, E., Lowe, S., Galvin, G. & Casey, K. (2007). Odour emissions from anaerobic piggery ponds. 2: Improving estimates of emission rate through recognition of spatial variability. Biores. Technol., 98(10), 1888–1897. DOI: 10.1016/j.biortech.2006.06.013.

42. Sówka, I., Sobczyński, P. & Miller, U. (2015). Wpływ sezonowej zmienności odorów emitowanych ze źródeł powierzchniowych pasywnych na zasięg oddziaływania zapachowego wybranej komunalnej oczyszczalni ścieków. Rocz. Ochr. Środ., 17(2), 1339–1349.

43. Sobczyński, P., Sówka, I. & Bezyk, Y. (2015). Charakterystyka zmienności emisji odorów z osadników wstępnycych i jej wpływ na zasięg oddziaływania zapachowego oczyszczalni ścieków komunalnych. In A. Kotowski, K. Piekarśka & B. Kaźmierczak (Eds.) Interdyscyplinarne zagadnienia w inżynierii i ochronie środowiska. Tom 6 (pp. 356–363). Wrocław: Of. Wydaw. Politek. Wrocław.

44. Meteomodel (2019, March). Pogoda i Klimat. Retrieved March 23, 2020, https://meteomodel.pl/aktualne-dane-pomiarowe/.