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Olfactometric Methods Application for Odour Nuisance Assessment of Wastewater Treatment Facilities in Poland

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No legal regulations and methodological recommendations have been adopted or developed in Poland, as yet, which could be used for olfactory impact assessment purposes. Objectives of this paper include a comparison between two olfactometric research methods employed in an olfactory impact assessment of *municipal wastewater treatment plants* (WTPs), and determination of their possible use in Polish conditions. Another objective of the paper was to identify the most odour nuisance facilities in the technological line of a WTP placed in Warsaw and currently undergoing modernisation and enlargement. In 10 measurement series 87 receptor points were determined for measurements to be taken using *field olfactometer* (FO); other 50 receptors were selected for tests using *delayed olfactometry* (DO). On the basis of FO and DO tests, the most significant odour sources were identified, namely the biofilter (which do not works correctly), screen room, collection chamber and the sand trap. Those sources are a part of the mechanical section of the WTP. Subsequent stages of wastewater treatment, namely the biological and sludge section, were substantially less nuisance in olfactory terms.
On the basis of the results obtained by each of the methods employed, the facilities were put in order of their olfactory impact: from facility generating the highest odour concentrations to these generating the lowest ones. The order of the facilities is quite similar both in the case of DO and FO method. No significant relationship was observed after comparison of two tested methods, marking the correlation coefficients. The average correlation (R^2 = 0.653) was only observed at the sand separator where there was small odour concentration.

1. Introduction

In most developed countries the number of complaints about the odour nuisance of industrial, farming or *municipal management facilities* (MMFs), including WTPs, has been growing (Latos et al., 2011). In Poland in the period of 2006 to 2007 the share of the complaints about odour nuisance, lodged by members of general public, in the total number of air protection cases increased from around 32 % to around 51 %, including MMFs which account for around 20 % of the problem cases (Kulig et al., 2009). There are over 2000 WTPs and around 1,000 solid waste management facilities operated in Poland (Kulig et al., 2010).
Almost all MMFs are potentially nuisance in olfactory terms. However special attention should be paid to WTPs in this context, because of the regulations applicable to the quality of wastewater discharged into water or soil, the number of WTPs operated in Poland has been growing continuously. In many cases those plants are located in a direct neighbourhood of residential areas, therefore the number of the facilities that local population could potentially complain of about has been on the increase, too.
The wastewater treatment process consists of several phases. Usually, the facilities of the technological line are various types of odorant sources (Stuetz and Frechen, 2001). The size and the

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characteristics of an olfactory contaminant plume from the facilities of a WTP depend not only on the phase of the wastewater treatment process but also on the composition of the inflowing wastewater which changes with time. The technology applied in a given plant influences the volumes and composition of emitted odorants, too. Many WTPs are redeveloped in order to reduce odorant emissions however in many cases, in spite of the modernisation efforts, the problem of odour nuisance remains.

Various methods are used for the assessment of the olfactory impact in WTPs (Gostelow et al., 2001). There are only few publications comparing different methods of odour testing employed to assess the olfactory impact of divers odorants emitters (Muñoz et al., 2010), for example those comparisons include papers by Bokowa (2008) and Nicolas et al. (2008). One of the sensory methods used for quantitative assessment of the determination of odour concentrations was described in the following standard: EN 13725 (2003) *Air quality – Determination of odour concentration by dynamic olfactometry* translated into Polish in 2007. This document specifies methodological recommendations restricted to the measurement of odours in high concentrations (in excess of 10 ou_E/m^3) coming from point sources or such surface sources from which the emission can be captured in special hoods. Another sensory method consists in evaluation of the odour concentration by means of a portable Nasal Ranger® field olfactometer. It can be used successfully for determination of small and quickly changing values of the odour concentration (in ou/m^3) in the near-the-ground layer of the air, which cannot be determined in accordance with EN 13725 (Kośmider and Krajewska, 2007; Muñoz et al., 2010).

Bokowa (2008) conducted comparative research focusing on two methods used for assessment of the olfactory quality of air: direct dynamic olfactometry based on the use of FO and DO described in EN 13725 standard. The values of olfactory concentrations obtained using FO were lower than those given by DO. This relationship was observed by Brandt et al. (2008), as well, and according to them it was connected with:

1. various approaches to the presentation and selection of the examined gas in the DO (triangular forced-choice) and the FO (YES/NO);
2. absolutely clean air in the laboratory environment, as compared with the air in the field where the air, by nature, quite often contains olfactory substances;
3. different measurement temperatures in the laboratory and in the field;
4. the fact that in FO method most assessing individuals give a result reflecting the identification threshold rather than the detection threshold.

Field olfactometry is more and more frequently used in the monitoring and evaluation of the olfactory impact, e.g. in municipal management facilities (Witherspoon and Barnes, 2004), agriculture (Brandt et al., 2008) and large-scale animal breeding (Kośmider and Krajewska, 2007).

2. Research objective and examined facilities

The objective of the research was to identify the most odour nuisance facilities in the technological line of a WTP situated in Warsaw and compare two olfactometric research methods employed in an olfactory impact assessment. The research was conducted in a large mechanical/biological/chemical WTP with the average daily flow of Q_{av} = 240,000 m^3/d and the maximum flow of Q_{max} = 320 000 m^3/d. The WTP consists of three main technological sections: the mechanical, the biological, and for sludge treatment (Figure 1). The mechanical section is made up of screens, sand traps and primary settling tanks. In the biological section, consisting of a bioreactors, apart from carbon compound purification processes, chemical dephosphatation, nitrification and incomplete biological denitrification processes take place. In the sludge section, some portion of the sludge is channelled back, in the recirculated sludge pumping station, to the wastewater treatment line whereas the excessive sludge is subject to thickening in gravitational sludge densifiers, anaerobic digestion and finally stabilisation on sludge storage yard.

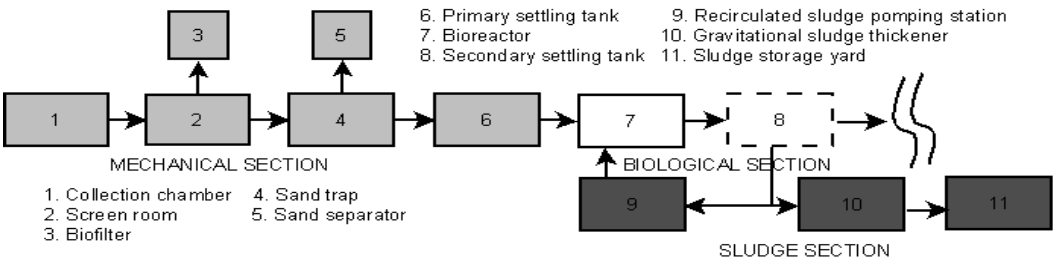

Figure 1: Wastewater treatment plant diagram

Facilities which potentially are the most significant odorant sources were selected for the research purposes, namely: the collection chamber covered by polyester/glass laminate lids and equipped with an air deodorising system (the facility no 1), a single screen situated in a closed and ventilated building of the screen room (the facility no 2), the biofilter bed (the facility no 3), one of the sand traps (the facility no 4), the sand separator (the facility no 5), one of the primary settling tanks (the facility no 6), one of the biological reactors (the facility no 7), the recirculated sludge pumping station (the facility no 8), one of the gravitational sludge densifier (the facility no 9), and a part of the sludge storage yard (the facility no 10).

3. Methodology

The levels of air contamination with odour were measured on a periodical basis, determining instantaneous concentrations. The receptor points were located inside the technological facilities, on their leeward edges and at some distance from them. In a direct neighbourhood of individual facilities of the wastewater treatment plant there is a potential joint impact of similar types of contaminants, therefore the research team made sure to conduct the research in a way that would make it possible to obtain information both about the impact of selected facilities and the WTP as a whole.
In the course of the research conducted on the premises of the WTP in the period of November 2009 to September 2010 measurements of odour concentrations were taken, employing FO, and the DO in line with the guidelines defined in EN 13725: (2007) standard. Determinations based on the use of FO were made at a larger number of points and more frequently. In 10 measurement series 87 receptor points were determined for FO measurements and 50 points for the DO. Eleven-month-long field research involved measurements and observations of weather conditions, as well.

3.1 Field olfactometry

Measurements of instantaneous odour concentrations were taken by means of FO. Two trained researchers participated in each measurement exercise. Sensitivity of their sense of smell to the odour of n-butanol was checked by means of a standard procedure employed to determine an individual sensitivity level of the sense of smell, developed by St. Croix Sensory, Inc. (St. Croix Sensory 2006). Each of the assessors had a separate olfactometer at their disposal. The measurements were taken on a parallel basis at the same time. For each measurement point at least 2 measurement repetitions were done. FO makes it possible to read out the value of „Dilution to Threshold" (D/T) ratio, corresponding to the ratio of the treated gas stream V_{clean} to the contaminated one V_{crude}. On the basis of D/T values individual estimations of odour concentrations Z_{ITE} [ou_E/m^3] were calculated (similar to that determined in accordance with EN 13725). To this end, the following dependence was used:

$$Z = \frac{V_{clean} + V_{crude}}{V_{crude}} = \frac{V_{clean}}{V_{crude}} + 1 \qquad [-] \tag{1}$$

for calculating two values of the dilution ratio (Z), corresponding to the first setting of V_{clean}/V_{crude}, at which the odour became perceptible (Z_{YES}), and the previous setting (Z_{NO}). Z_{ITE} is a geometric mean of the Z_{YES} and Z_{NO} values.

$$Z_{\mathrm{ITE}} = \sqrt{Z_{YES} \cdot Z_{NO}} \qquad [-] \qquad (2)$$

Values of the odour concentration c_{od} [ou/m^3] were calculated as a geometric mean of the n set of all individual estimations (Z_{ITE}) for a given receptor point.

$$C_{od} = \sqrt[n]{\prod^{n} Z_{ITE}} \qquad [ou/m^3] \qquad (3)$$

3.2 Delayed olfactometry

DO examinations were carried out in an olfactometric laboratory, using T07 olfactometer in accordance with EN 13725(2003) standard. The air samples were collected to Nelophan bags and determined within the period of time not exceeding 30 h from the moment of collection. The samples were collected:

- using hood methods:
    - by means of a floating device with the active area of 1 m^2 (0.8 x 1.25), used for collection of samples from liquid sources, namely from the facilities No 4, 6 and 7; and
    - by means of a hood with the area of 1 m^2 for active sources, namely from 3 and 10;
- ”from the air” above the surface of the source, i.e. above the cover of the facility No 1; in the facility No 2 from above the surface of the wastewater near the mechanical screen; and in the facility No 5 from above the free surface of the wastewater.

4. Results and discussion

The results of the research are shown in Tables 1 and 2. In the facility No 2, near the facility No 5 and directly above the facility No 1, the air samples used for DO determinations were collected in a way most similar to FO-based measurements. Almost in all the cases the odour concentration levels determined using FO were much lower than the values obtained as a result of determinations done in a laboratory environment. However in the case of the facility No 5 the values obtained with FO on 25/11/2009 were higher as a result of the fact that the samples for DO were collected several minutes earlier than the FO measurement was done. During FO measurement the sand separation process entered a dynamic phase, manifested in strong turbulence of the wastewater and deposited sand.

Both olfactometric methods were compared for individual facilities of the technological line. But it is important to point out that only in the case of facilities No 1, 2 and 5 the air samples used for DO determinations were collected straight “from the air”, i.e. in a way most similar to OT-based measurements. Practically, the results given by individual research methods can be compared only for those points. In the case of the remaining facilities, the measurement points for OT were situated inside the technological facilities, on leeward edges of the facilities and at some distance from them whereas the air samples to be used for laboratory analyses were collected from the source using hood methods. The correlation coefficients R^2 were determined at the significance level of 0.05 for the facilities No 1, 2 and 5 on the basis of the results obtained by both research methods. They amount to: 0.206; 0.133; and 0.635 respectively. A moderate correlation of the results given by both methods was found only in the case of the facility No 5 which is characterised by relatively low values of the odour concentration ranging from 5 to 8 ou/m^3 for FO and from 35 to 90 ou_E/m^3 for DO.

The results of the entire measurement exercise have been averaged for individual facilities, separately for FO and DO. It is important to point out that the number of FO determinations was considerably larger than the number of DO determinations, therefore to ranking facilities in terms of odour concentrations was taking into consideration only the results of FO measurements taken parallel to the DO. On that basis the facilities were put in order of their odour nuisance: from those with the highest nuisance to those with the lowest one. The results obtained by both methods make it possible to create a similar ranking of the facilities in terms of the odour concentrations (Figure 2).

Table 1: Odour concentrations [ou/m^3] determined using FO for individual facilities within WTP

No. of facility according to section 2	Date									
	09.10. 2009	25.11. 2009	09.03. 2010	23.03. 2010	12.04. 2010	20.04. 2010	11.05. 2010	15.06. 2010	20.07. 2010	07.09. 2010
1	95	49	53	28	12	163	163	354	91	395
2	222	347	222	142	296	19	49	22	18	141
3	-	-	471	278	11	153	268	43	19	347
4	471	370	205	234	10	22	37	14	9	255
5	-	268	91	14	8	17	12	10	5	5
6	246	10	12	11	10	8	12	31	-	-
7	-	5	6	5	5	5	-	-	-	-
8	-	5	7	22	5	4	-	22	-	-
9	-	222	10	8	16	6	-	22	534 549	43
10	22	12	91	43	22	50	22	10	5 7 50	5

Table 2: Odour concentrations [ou_E/m^3] determined using DO for individual facilities within WTP

No. of facility according to section 2	Date						
	26.11. 2009	23.03. 2010	20.04. 2010	11.05. 2010	15.06. 2010	20.07. 2010	07.09. 2010
1	4,743	80	6,633	1,414	1,612	474	1,296
2	2,608	26,926	26,870	3,074	107	38,497	12,000
3	-	17,321	10,954	7,550	4,604	7,769	9,000
4	400	232	1,249	1,062	98	1,052	3,098
5	186	42	33	40	60	260	63
6	155	40	78	58	99	-	-
7	46	45	35	55	90	-	-
10	140	111	271	1,400	165	-	157

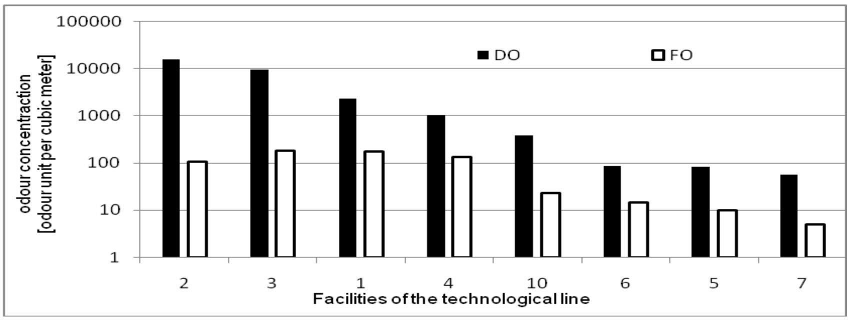

Figure 2: Ranking of the facilities (numbered according to the Figure 1) in terms of the odour concentrations

5. Conclusions

The research conducted so far shows that odour concentrations determined using field olfactometer are lower than those determined using delayed olfactometry (Bokowa, 2008; Brandt et al., 2008). It is confirmed by results of the research activities covering the surface of the collection chamber, screen room and sand separator where air was taken for analysis in the same places and using both research methods. In the opinion of authors, the main role in this discrepancies plays difference between odour-free laboratory environment and rather inherently no scentlees air in field conditions. Apart from the reasons pointed by Bokowa and Brand, could also be important that discrepancies between results

given by both methods may be caused by the fact that different procedures were used for members selection of two different panels (Barczak et al., 2010).
On the basis of the research employing FO and DO the most significant sources of odorants can be identified, namely the biofilter, the screen room, the collection chamber and the sand trap. Those sources are a part of the mechanical section of the wastewater treatment process. The biofilter is worth mentioning in this context because it failed to perform as a unit designed to clean the air contaminated with odorants. The results obtained with the help of FO point to the gravitational sludge densifier as another significant source of odorants. The next phase of the wastewater treatment process, namely the biological section, is substantially less nuisance in olfactory terms. This conclusion is consistent with the results of the questionnaire survey conducted by Podedworna et al. (2010). The results of the research may form a basis for decisions on technological modifications.
The ranking of the facilities put in order of their olfactory impact: from the strongest to the weakest one is very similar both in the case of the DO and the method based on FO.
It is important to try and standardise the methods employed to evaluate the olfactory impact of individual facilities. Application of various methodologies may lead to differences in conclusions drawn on their basis, e.g. in environmental impact assessment procedures, especially if permissible odour concentration levels are set without any reference to the research method employed.

References

Barczak R., Sówka I., Nych A., Skrętowicz M., Zwoździak P., 2010, Application of the standard Sniffin' Sticks method to the determination Odor Inspector's olfactory sensitivity in Poland. Chemical Enginnering Transactions, 23, 13-18, DOI: 10.3303/CET1023003.

Bokowa A., 2008, Ambient Odour Assessment- Comparison of Two Techniques used for Assessing Ambient Odours, 3rd IWA Odour and VOCs Conference: Measurement, Regulation and Control Techniques Barcelona, October 8-10 2008.

Brandt R.C., Elliott H.A., Adviento-Borbe M.A.A., Wheeler E.F., Kleinman P.J.A., Beegle D.B., 2008, Field olfactometry assessment of dairy manure land application methods, Am. Soc. Agric. Biol. Eng. Annu. Int. Meet. 11, 6744-6759.

Gostelow P., Parsons S.A., Stuetz R.M., 2001, Odour measurements for sewage treatment works, Water Res. 35(3), 579-597.

Kośmider J., Krajewska B., 2007, Determining temporary odour concentration under field conditions - Comparison of methods, Pol. J. Environ. Stud., 16(2), 215-225.

Kulig A., Lelicińska-Serafin K., Podedworna J., Sinicyn G., Heidrich Z., Czyżkowski B., 2009, The survey of odorant sources in the wastewater and solid waste management in Poland and evaluation of their noxiousness on the basis of questionnaire examinations, Przemysł Chemiczny. 88(5), 484-492 (in Polish).

Kulig A., Lelicińska-Serafin K., Podedworna J., Sinicyn G., Heidrich Z., Czyżkowski B., 2010 Identification, Inventorying and Characteristics of Odorant Sources in Municipal Management in Poland, In: Contemporary Odour Issues, Eds Szynkowska M.I., Zwoździak J., WN-T, Warszawa, 14-53 (in Polish).

Latos M., Karageorgos P., Kalogerakis N., Lazaridis M., 2011, Dispersion of odorous gaseous compounds emitted from wastewater treatment plants, Water Air Soil Pollut. 215(1-4), 667-677, DOI: 10.1007/s11270-010-0508-8.

Muñoz R., Sivret E.C., Parcsi G., Lebrero R., Wang X., Suffet I.H., Stuetz R.M., 2010, Monitoring techniques for odour abatement assessment, Water Res. 44(18), 5129-5149, DOI: 10.1016/j.watres.2010.06.013.

Nicolas, J., Romain, A.C., Delva J., Collart C., Lebrun V., 2008, Odour annoyance assessment around landfill sites: methods and results, Chemical Enginnering Transactions, 15, pp. 29-36.

Podedworna J., Kulig A., Heidrich Z. and Sinicyn G., 2010, Assessment of the olfactory impact of wastewater mechanical treatment processes. Przemysl Chem. 89(4), 517-523 (in Polish).

St. Croix Sensory Inc., 2006, Standard Procedure for Testing Individual Odor Sensitivity.

Stuetz R.M., Frechen F.-R., 2001, Odours in Wastewater Treatment. Measurement, Modelling and Control, In: IWA Publishing, Aliance House, London.

Witherspoon J.R., Barnes J.L., 2004, Comparison of methods used to measure odour at wastewater treatment plant fencelines, VDI Environmental Odour Management Conference - Cologne, Germany, <www.nasalranger.com/Media.cfm> accessed 28.03.2012.