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Odour Monitoring of a Municipal Wastewater Treatment Plant in Poland by Field Olfactometry

Radosław Barczak*, Andrzej Kulig

Faculty of Building Services, Hydro and Environmental Engineering, Warsaw University of Technology, 20 Nowowiejska Street, 00-653 Warsaw, Poland
Radoslaw.Barczak@is.pw.edu.pl

At the mechanical-biological municipal wastewater treatment plant, located in Poland in Mazovia Voivodeship, and its surroundings odour measurements using the field olfactometry method were conducted. During five measurement days 15, 21, 22, 20 and 22 receptor points were chosen. Receptor points were selected on the leeward side, at the edge and downwind at objects of technological line which were the most significant in terms of the potential for odour nuisance: the screen room, the longitudinal purged sand trap, primary settling tanks, the connecting chamber, chambers of phosphorus removal, the distribution chamber, chambers of activated sludge, secondary settling tanks, the tank of excess sludge, the digested sludge tank, the sludge processing building, where the sludge is dewatering, and in the surroundings of the sludge drying building. All measurements involved 2 trained assessors. For each measurement point (receptor) at least 2 replicates were made. Based on the conducted research, objects of the technological line with the highest value of the odour concentrations and their ranges of impact were determined. The highest value of odour concentrations was equal to 43 ou/m^3 and measured at the surface of the longitudinal purged sand trap and over the tank of excess sludge. Maximum odour concentrations in the vicinity of the distribution chamber, above chambers of phosphorus removal, above the connecting chamber, in the vicinity of chambers of activated sludge, at the edge of secondary settling tanks, in the vicinity of the screen room, next to open door to sludge processing building were 22, 6, 11, 4, 5, 16, 31 ou/m^3 respectively. Range of impact defined as odour detection of individual objects did not exceed 50 m.

1. Introduction

In Poland there are more than 2000 municipal wastewater treatment plants (WWTPs) with average daily flows greater than 100 m^3/day and this amount has been growing continuously due to European Union legislative requirements and discharge fees requiring high quality environmental discharges. Community encroachment coupled with an increased environmental awareness of communities, has meant the population of the areas near these facilities expressed a growing interest in the right to be free from malodorous air (Cheng *et al.* 2007). This impact has grown significantly with the expansion of suburbia and the associated rural and industrial encroachment (Beghi *et al.* 2012) to the close vicinity of WWTPs.

WWTPs may cover areas of land larger than 50 ha. The wastewater treatment process consists of several phases (Vincent 2001). Usually, the WWTP's facilities of the technological line present a range of odorant sources, including point, surface, unorganized and periodic (Barczak, Kulig & Szyłak-Szydłowski 2012) which occurred some distance from one another. Moreover, procedures for determining odour emissions from diffuse or temporary and fugitive sources have not yet been standardized (Kośmider & Krajewska 2007). The size and the characteristics of an olfactory contaminant plume from the facilities of a WWTP depend not only on the phase of the wastewater treatment process but also on the composition of the influent wastewater, which is variable over time. The technology applied in a given plant also influences the odour character and odour concentrations. Therefore, WWTPs should be treated as a group of different odour sources from individual technological objects (Giuliani *et al.* 2013). In some cases during particular spatial distribution of the technological line objects and during particular weather condition, mostly wind speed and direction, emission from every individual odour source can affect the surroundings independently. At some distance from the

source odour emission in the ground surface air layer is fast-changing and values of odour concentrations are less than 10 ou_E/m^3, but still high enough to affect local communities. Measurement at this small value odour concentration can not be carried out in accordance with standard EN 13725 (2003), because it is impossible to perform the appropriate number of dilutions. However, such assays may be performed in situ by dilution dynamic olfactometry using a field olfactometer such as Nasal Ranger (Kośmider & Krajewska 2007).
The number of parameters affecting the odour nuisance of municipal WWTPs, makes the odour impact assessment (OIA) very difficult. Despite this, environment odour impacts must be included in environmental impact assessments (Kulig 2004). Minimizing the olfactory impact of WWTPs is one of the greatest challenges for the wastewater sector (Longhurst *et al.* 2004).
The measurement of the odour is only part of the olfactory impact assessment procedure. In order to perform an odour impact assessment, it is necessary to determine the frequency of measurements (Naddeo *et al.* 2012). In countries where there are no legislative provisions and methodological guidelines used in assessing odours, such as Poland, the authors apply different measurement methods and results are often differently interpreted. The aim of this study was to perform odour monitoring of a WWTP located in Poland by field olfactometry.

2. Description of the object

At the mechanical-biological municipal wastewater treatment plant which technological scheme is shown in the Figure 1, with average daily flow $Q_{av.}$ equal to 12 238 m^3/d located in Poland in Mazovia Voivodeship and in its surrounding odour monitoring using field olfactometry (FO) method was proceed.

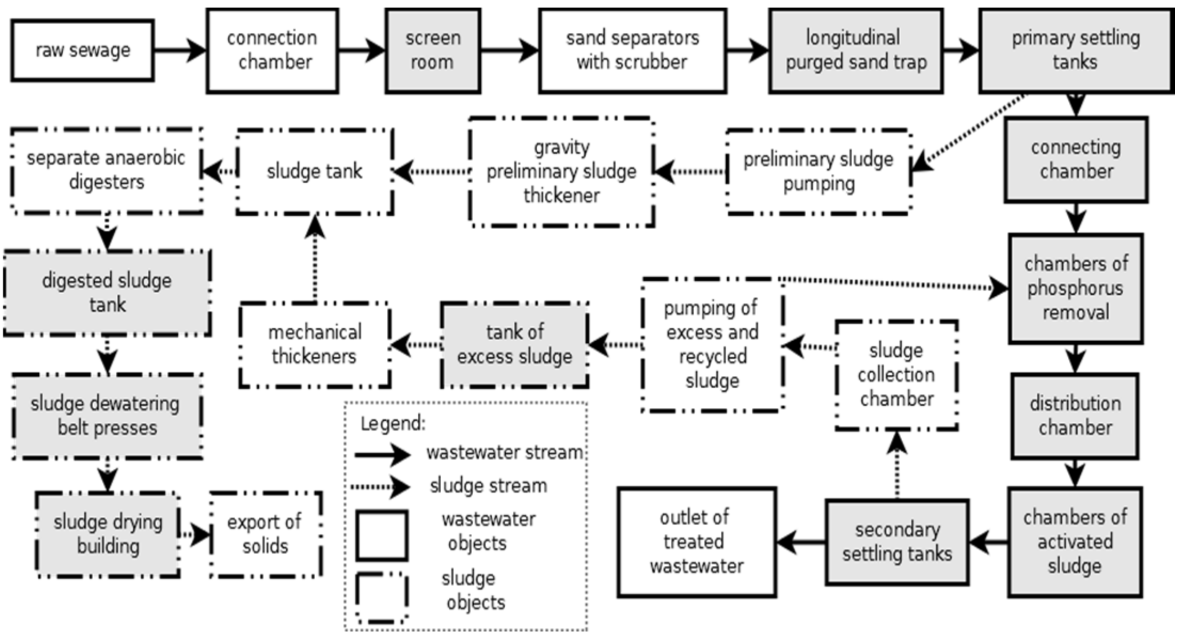

Figure 1: Technological scheme of Wastewater Treatment Plant

3. Methodology

The proposed procedure for the measurement of odour concentrations (c_{od}) using FO at the municipal WWTP and its surrounding, show in the Figure 2, consist of three main stages: preparation of measurements, conduct field measurements, and analysis of results and the report from studies.
Characterization of the WWTP in terms of odour nuisance was performed in the initial phase. For this purpose were got acquainted with the documentation of technology and spatial distribution of objects at WWTP. On the basis of documentation such as the plan of the WWTP, description and technological diagram, characteristics of the technological objects and their distribution, characteristics of emission variation over the time, the solutions limiting and control odour nuisance potential sources of odours were identified, which were the individual elements of the technological wastewater and sludge treatment. On 3rd June 2013 the site visit, interviewed with WWTP employees about the odour nuisance of the technological facilities, and an organoleptic assessment of the WWTP plant were carried out. Most relevant odour sources were localized and in their surroundings preliminary receptor points were determined.

After completion of the first stage, FO measurements began. Due to the variable nature of odour emissions from WWTPs over the time, this step consisted of four runs. In determining the amount of measurement series variability meteorological conditions and proper operation of the technological system was taken into account. Receptor points were selected on the leeward side, at the edge and downwind of the object of technological line which were the most significant in terms of the potential for odour nuisance (grey fields at scheme presented at Fig. 1): the screen room, the longitudinal purged sand trap, primary settling tanks, the connecting chamber, chambers of phosphorus removal, the distribution chamber, chambers of activated sludge, secondary settling tanks, the tank of excess sludge, the digested sludge tank, the sludge processing building, where the sludge is dewatered, and in the surroundings of the sludge drying building. Moreover, background measurements were done on the windward side of the WWTP. In 2013 on 11th June and 2nd, 3rd, 4th and 5th July for FO measurements 15, 21, 22, 20 and 22 receptor points were chosen, respectively. All measurements involved 2 trained assessors whose N-butanol sensitivity were within the range accordance with procedure, determining individual olfactory sensitivity, developed by St. Croix Sensory, Inc (St. Croix Sensory 2006). Those assessors were being able to distinguish between odours coming from the various objects of technological line in the municipal WWTPs. Each of the assessors had a separate field olfactometer at their disposal. Measurements were performed in parallel, simultaneously. For each measurement point (receptor) at least 2 replicates were made. c_{od} were calculated according to procedure described elsewhere (Barczak, Kulig & Szyłak-Szydłowski 2012, Kośmider & Krajewska 2007). In each series of measurement receptor points were determined on the basis of preliminary receptor points identified in the stage I and taking into account the meteorological conditions, mainly the wind speed and direction. The wind directions and the ambient temperature are parameters with a high influence in the odour footprint of WWTPs (Perez *et al.* 2010). In order to determine the range of the impact of odour sources receptor points were localized into downwind to source depending on the wind speed and direction and the altitude of the emission sources.

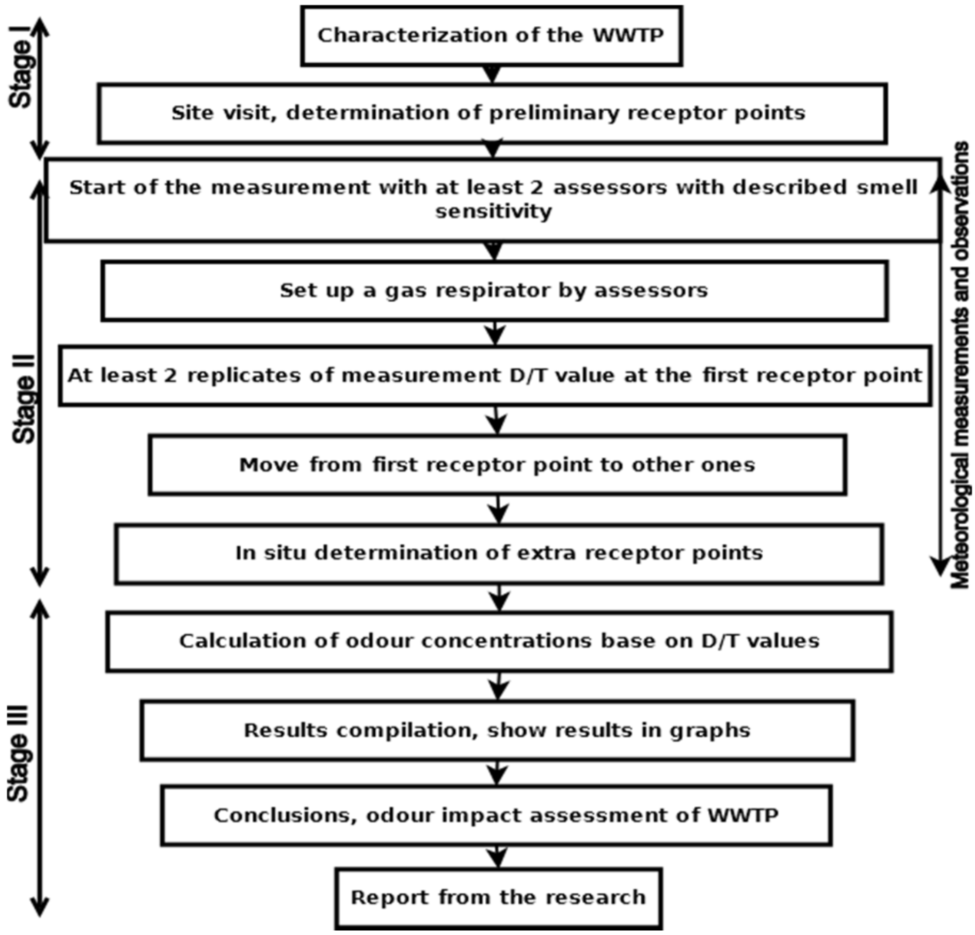

Figure 2: Block diagram of the olfactometric measurement procedure using field olfactometer at municipal wastewater treatment plant

At the time of accession to olfactometry measurements assessors set up a gas respirator, equipped with a filter that meets the requirements of EN 14387 (2004) and EN 143 (2000) European standards and wore it throughout the duration of the measurement series, during the movement from one receptor point to another. Gas respirators were used to reduce the smell adaptation to the conditions prevailing during measurements. Gas respirators were removed by assessors only at receptor points just prior to the olfactometry measurements.

Meteorological measurements, wind speed and direction, temperature and atmospheric humidity were made at each point of the receptor prior to olfactometry analysis during the entire series of measurements. Measurements of wind speed and direction are very important when determining the receptor points, designated to determine the extent of the impact of various odour sources.

Due to the time-varying nature of odour emissions at the WWTP, as well as to potential sources of accidental and unforeseen at the initial stage due to eg. failure or faulty operation of individual components within the process, the potential exists for the emergence of additional sources of odour, other than determined in the first step. Therefore, when performing a series of olfactometry measurements determined to keep extra receptor points. To this end, during movement between designated receptor points, in places where there may be a potential impact of unexpected odour nuisance in the first stage, it was taken off the gas respirator with the intention of olfactometry analyzing. If no smell were detected, gas respirator masks were set up again immediately. The result at a given point receptor was 0 ou/m^3.

The third stage, which is the analysis of results and report from the study was made after completion of all measurement series. The report included the information obtained during the first stage, including description of technological line. For all receptor points results of measurements of the c_{od}, expressed in odour unit ou/m^3, with a detailed description of the methodology of olfactometry measurements. It indicated the source of odour in the surroundings which measured the highest and lowest values of the c_{od}, along with information on the possible range of individual objects with respect to meteorological conditions. The report presented graphically the location of the receptor points. It presented conclusions of the studies relating to: the c_{od} values measured in the vicinity of individual technological objects, the range of the impact these objects, identify objects in an environment where measured the highest values c_{od} and necessity for solutions to reduce odour emissions.

4. Results and discussion

Based on the study objects of the technological line with the highest values of the c_{od} were selected. Ranges of their impact were determined. Results of the c_{od} for the receptor points shown in the Figure 3 related to the selected objects of technological line are shown in the table 1.

Table 1: Results of odour concentrations measured by field olfactometry at wastewater treatment plant

Object of technological line	Receptor point no. / c_{od} [ou/m^3] / distance from the object of technological line to the receptor point [m]
Building of screen room	11/4/1; 31/16/1; 31/2/1; 54/2/10; 59/0/10; 30/3/15; 41/2/15
Longitudinal purged sand trap	7/43/0; 7/31/0; 27/22/0; 27/43/0; 27/8/0; 27/43/0; 8/14/10; 58/2/15; 39/4/23; 9/2/25; 28/2/25; 28/0/25; 52/2/30; 40/0/50
Primary settling tank	22/5/0; 22/5/0; 50/3/0; 22/5/0; 5/0/10; 51/0/15; 57/0/20; 21/0/25; 21/0/25
Connection chamber	23/11/0; 23/11/0; 23/11/0; 23/11/0; 38/2/5; 24/2/5; 38/4/5
Chamber of phosphorus removal	25/6/0; 25/5/0; 25/2/0; 25/6/0; 56/3/2; 6/10/4; 24/4/4; 24/3/4
Distribution chamber	1/2/0; 1/10/0; 1/10/0; 1/22/0; 1/10/0; 2/0/7; 36/0/7; 36/0/7; 36/0/7; 45/4/10
Chamber of activated sludge	19/2/0; 19/2/0; 47/4/0; 19/3/0; 3/3/1; 20/0/6; 20/0/6; 20/0/6; 4/0/7; 46/3/30
Secondary settling tank	17/2/1; 17/2/1; 48/2/1; 49/2/1; 17/2/1; 18/0/5; 18/0/5; 18/0/5
Tank of excess sludge	14/43/0; 33/3/0; 33/3/0; 43/2/0; 13/13/25
Sludge processing building	34/3/3; 35/17/3; 34/3/3; 35/31/3; 35/31/3; 35/31/3; 34/3/3; 55/10/10; 61/8/13
Sludge drying building	60/2/3; 12/3/4

In the closest vicinity of the building of screen room the c_{od} ranged from 0 to 4 ou/m^3, close to the gates of the building values of 16 ou/m^3 were measured. Within 10 to 15 meters from the building the c_{od} values ranged from 2 to 3 ou/m^3. On the surface of longitudinal purged sand trap were measured values of the c_{od} ranged from 8 ou/m^3 on 4th July 2013, by 31 ou/m^3 on 2nd July to 43 ou/m^3 on 11th June and 3rd and 5th July 2013. On the leeward side at a distance of about 25 to 30 meters of longitudinal purged sand trap the c_{od} values ranged from 0 to 4 ou/m^3. On 3rd and 5th July in 50 meters from this object odour was not detected, the c_{od} values were equal to 0 ou/m^3. In the vicinity of the primary settling tank odours were not detected. The c_{od} values ranging from 2 ou/m^3 to 4 ou/m^3 measured 5 meters from the connection chamber might be due to the effect of both the coupling connection chamber and the chamber of phosphorus removal. Above the chamber of phosphorus removal the c_{od} values ranged from 2 to 6 ou/m^3 and at a distance of 4 m away from the object from 3 to 10 ou/m^3. Higher values of the c_{od} measured at a distance from the chamber of phosphorus removal than above its surface may indicate the overlapping of odours from another object, probably from connection chamber at the surface of which during the three series of measurements measured value of the c_{od} equal to 11 ou/m^3. On July 4th 2013 in the vicinity of the distribution chamber measured the c_{od} value was equal 22 ou/m^3 and the range of influence of this object was higher than 10 m. At a distance of 10 m from the edge of this source measured value of 4 ou/m^3. In the remaining days measured values range from 2 to 10 ou/m^3 and the ranges of influence were less than 7 meters. In the surrounding of the chamber of activated sludge the c_{od} ranged from 3 to 4 ou/m^3 in 4 cases, the range of impact was less than 7 meters. On July 4th 2013, 30 meters away from object was measured value equal to 3 ou/m^3. At the edge and at the surface of the secondary settling tank the c_{od} ranged from 2 to 5 ou/m^3. At the distance of the object from 5 to 25 m odours were not detected. On 11th June 2013 over the tank of excess sludge was obtained the c_{od} value equal to 43 ou/m^3 and 25 meters away from this object 13 ou/m^3. During the consequent measurements days the tank of excess sludge the c_{od} values ranged from 0 to 3 ou/m^3. Close to the opened gates of the sludge processing building the c_{od} values ranged from 17 to 31 ou/m^3. Between the sludge processing and the sludge drying buildings the c_{od} values ranged from 8 to 10 ou/m^3. At a distance of 3 meters from the sludge processing building the c_{od} ranged from 2 to 3 ou/m^3. At the desulfurization of biogas station and digested sludge tank detected no odour. In all cases background the c_{od} on the windward side of the WWTP was 0 ou/m^3.

In the Figure 3 all receptor points from all measurement days and the theoretical range of odour impact of individual object of technological line were shown. The experimental ranges of odour impact were determined as a radius equal maximum distance from technological object to receptor point, where the positive value of the c_{od} was measured.

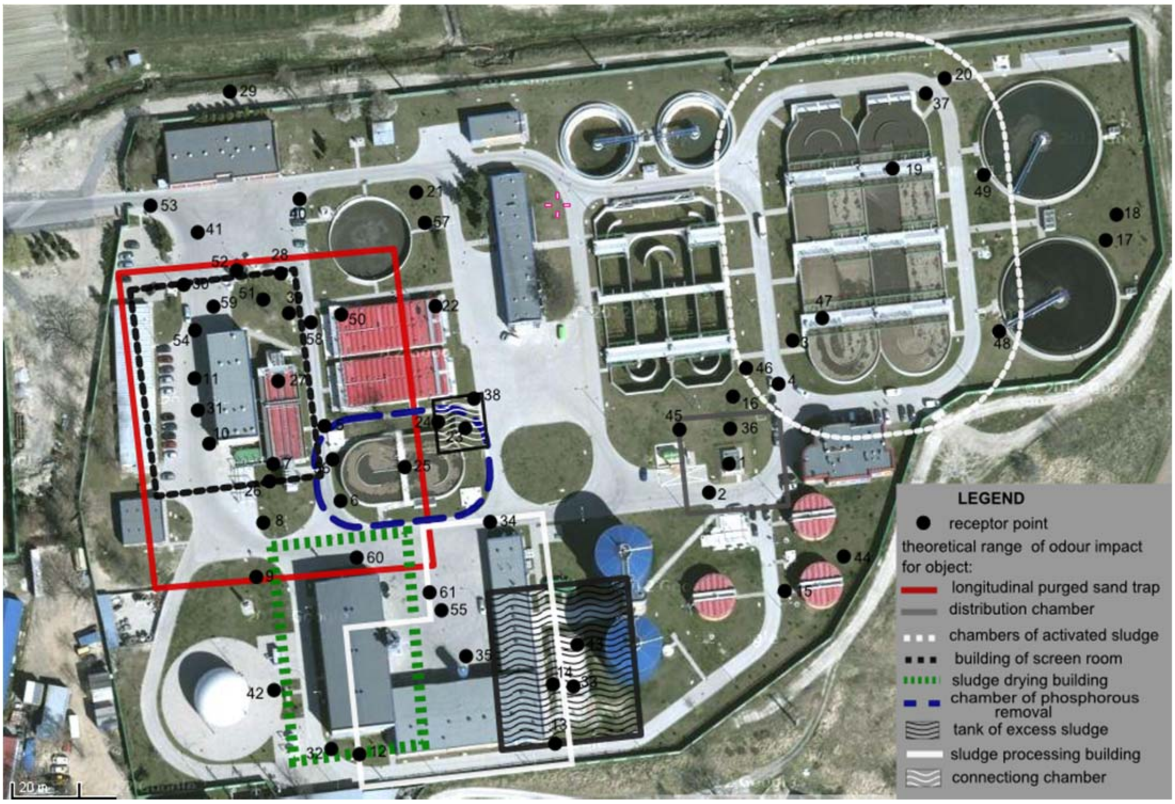

Figure 3: Spatial distribution of technological object of the municipal wastewater treatment plant and the estimated range of their impact

During the measurement runs the impact of the technological individual objects has contained within the fence line of WWTP, however based on theoretical range line, at the different weather condition, like south wind for example, emissions from chambers of activated sludge can be detected behind fence line of WWTP. The highest odour concentration values were measured in the vicinity of the object of the pretreatment stage: sand trap, distribution chamber, sieves building and sludge processing stage: tank of excess sludge and building of sludge processing correspond with the observation of Capelli et al. (2009) whose reported in a research of odour emissions for 17 WWTP in Italy, that the main odour source is the first treatment stage, decreasing while the process goes forward, pointing that collecting system has more influence in odour formation than treatment stages and is high as well for object belongs to sludge treatment. Moreover, Karageorgos et al. (2010) reported that the flow distribution chambers were identified as sources with the high odour impact.

5. Conclusions

In this study the odour monitoring procedure of one WWTP using portable dynamic olfactometer Nasal Ranger was described. According to this procedure objects of technological line in the vicinity of whose were measured highest value of the odour concentrations and determined their range of impact. Moreover, the methodology identified the potential for the emergence of additional sources of odour, other than determined during measurements preparation due to the time-varying nature of odour emissions at the WWTP, as well as potential sources of accidental odours and those unforeseen at the initial stage due to eg. the failure or faulty operation of individual components within the process. However, the Nasal Ranger field olfactometer range has not been evaluated in interlaboratory comparison studies yet, and the accuracy and reproducibility of odour measurements by this devices are unknown at this moment and should be subject of future studies.

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