CHEMICAL ENGINEERING TRANSACTIONS
VOL. 68, 2018
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet
Guest Editors: Selena Sironi, Laura Capelli

ISBN 978-88-95608-65-5; ISSN 2283-9216

Methodological Aspects of Odorimetry in Environmental Audits of the Wastewater Treatment Plants

Andrzej Kulig*, Mirosław Szyłak-Szydłowski

Faculty of Building Services, Hydro and Environmental Engineering, Warsaw University of Technology, 20 Nowowiejska Street, PL-00653 Warsaw, Poland
Andrzej.Kulig@is.pw.edu.pl

Environmental assessments play an important role among environmental protection instruments in the economy. Three main cases of such assessments can be distinguished: forecasts of the effects of the implementation of the plan, program, strategy (i.e. the so-called strategic assessments), environmental impact assessment of planned projects, as well as environmental audits, including post-implementation assessments, of existing installations and facilities. In each case, the objectives of the procedure can be different and the assessment methods are defined differently too (Barczak and Kulig, 2017; Zarra et al., 2014). Generally, it is to show that a newly built facility, also modernized or extended, meets the environmental protection standards included in legal regulations and administrative decisions. In the case of modernization or extension of the facility, it must additionally be shown that the ecological goal of the project has been achieved. As far as odour effects are concerned, the main goal of the research is to determine whether the plant (installation) being potential source of odorants emission put into operation will not be nuisance for other users of the area and residents in general. In the article, the methodological aspects of odour testing in post-implementation assessments in sewage management were analysed on the example of a modernized and expanded wastewater treatment plant (installation of the WWTP) located in Central Poland. Field studies on the impact on the environment were carried out based on scented air pollution of objects causing odour nuisance in the analysed area.

1. Introduction

In Poland, environmental assessments in the wastewater sector play an important role because it is a sector in which many new installations are still being built and existing ones are being modernized and expanded. At the same time, the problem of the environmental impact of sewage management facilities is extensive from the point of view of the type of impact. In addition to the impact of treated wastewater on the receiver, emission of pollutants into the air and soil as well as noise emission and solid waste impact on the environment, a very important role plays the odorants emission. The scope of post-implementation analysis in each case is slightly different.

The basic legal regulations regarding environmental assessments, including post-implementation analyses, include: the Act of 27th April 2001 - *Environmental Protection Law* [1], the Act of 3th October 2008 *on provision of information on the environment and its protection, public participation in environmental protection and environmental impact assessment* [2], hereinafter referred to as the EIA Act, and the Regulation of the Council of Ministers of 9th November 2010 *on types of projects likely to have significant effects on the environment* [3].

In the case where the air quality odour standards are not formally established, and with this situation we are currently dealing in Poland, a good solution is to perform a comparative analysis of the intensity of the odour impact before and after modernization and possible expansion of the installation. Due to the fugitive nature of odorant emissions from WWTPs facilities (as low, usually superficial sources), the research program must assume carrying out many measurement series with numerous receptor points (Barczak and Kulig, 2016).

Theoretical considerations are illustrated on the example of the results of the examinations of medium modern installation of the WWTP. It was assumed that the application of the test method in a plume is more effective, i.e. with fewer measurements, more information is obtained on the scent effect of treatment plants. It should

be added that the problem of onerous impact of the odorous sewage treatment plant and residents' complaints about this nuisance is seasonal. The most common complaints against wastewater in the municipal sector are recorded in the warm period of the year (in the summer), that usually is assessed as less favourable due to the olfactory impact of WWTPs facilities (Kulig, 2004). Therefore, studies should be carried out for a longer period of time, preferably in an annual cycle. The aim of the work were post-implementation analysis and evaluation of the investment project entitled “Modernization and extension of the sewage treatment plant" in the aspect of impact on air quality in terms of odour.

2. A brief characteristic of the tested WWTP

The field examinations were realized on the example of a mechanical and biological treatment plant with increased efficiency of biogens removal, using activated sludge in the process of purification. The maximum hydraulic capacity of WWTP is 60 thousand m^3/day. The investigated wastewater treatment plant is located in province (voivodeship) Mazovia, in the vicinity of the Warsaw agglomeration. The plant location on the town map is shown in Figure 1. In Figure 2 is presented a general view of the technological facilities of WWTP.

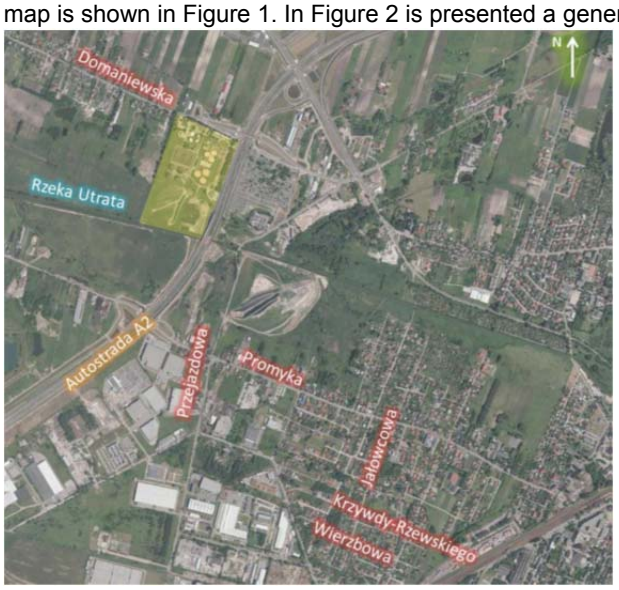


Figure 1. The location of the sewage treatment plant under consideration on the town map

Figure 2 The location of the technological facilities of WWTP (before modernization and extension)

As part of the investment, the installation of the treatment plant was enlarged, among others for two new biological reactors with two secondary settling tanks of construction and volume similar to existing devices, a new separated fermentation chamber with an active capacity of min. 4500 m3 and biogas cogeneration unit. A number of facilities and installations have been modernized.

3. Materials and methods

3.1. The olfactometric research programme

The research programme has been performed at the measuring and observational points (receptors), located within and around the WWTP area. The assessment of odour nuisance of the treatment plant included field tests of odorimetric air quality with direct monitoring (control) of the current meteorological conditions in two periods: from April 28 to June 3, 2015, i.e. before the modernization and extension of the installation, and from 20/05/2016 to 26/04/2017, i.e. after full technological start-up of the plant. In the first period, in 2015, 10 research series of odour concentration and odorimetric observations were carried out, in which 360 measurement and observation points were determined: 162 receptors within the treatment plant and 198 outside its borders. In the second period, in 2016-2017, twelve measurement series were carried out at the receptors located in the area (300 points) and around the treatment plant (144 points). Receptor points were determined mainly by the area in which the odours were uniquely identifiable as to their origin.
Due to changes in the intensity of the odorous impact of technological objects at different times of the day, depending on the operation of equipment and installations, operational activities, temporary meteorological conditions and many other factors, attention should be paid to the need to take into account this variability. Figures 3 and 4 present the distribution of research activity in two periods: in years 2015 and 2016-2017, i.e. before and after technological changes in wastewater treatment plant. In each measurement series on the

windward side of the sewage treatment plant the background of air pollution with aromatic substances has been marked.

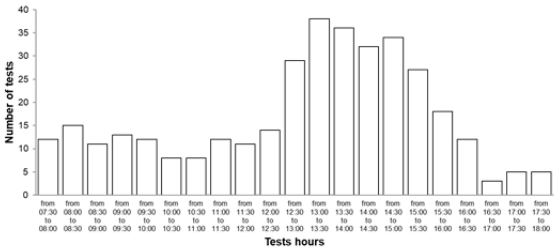


Figure 3. Daily time distribution of field tests in 2015

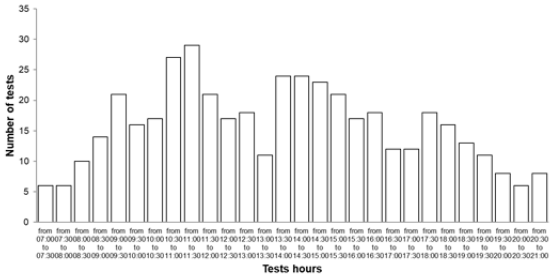


Figure 4. Daily time distribution of field tests in 2016-17

3.2. Methods of the odour tests

The olfactometric studies have been conducted using a method based on the identification and characterization of a plumes of smell emitted from the sources under post-implementation assessments and their results were compared with the similar tests carried out before the investment.
The article presents the results of the assessment of the intensity of the odours in sensory studies on a 6-point scale (from i = 0 to i = 5) and the measurement of the odour concentration (using the Nasal Ranger® portable field olfactometers), partly under rules of PN-EN 13725 (2007) standard.

3.3. Methods of meteorological measurements

Olfactometric measurements were accompanied by measurements and observations of the current meteorological situation: wind direction and velocity, temperature and relative humidity of the air, the degree of cloudiness and the occurrence of atmospheric precipitation. Information about meteorological conditions was used directly during *in-situ* investigations and each time was recorded at the results of the measurements, as the necessary data for analysis of air quality status. Meteorological parameters were defined in each of the receptor points. The wind direction was determined by the plume method each time before the observations and measurements began. Wind velocity measurement has been performed using the Kestrel 4500 NV manual anemometer with vane impeller (rotor). Measuring the direction and velocity of the wind were performed at a height of 2 m. Measurement of temperature and relative humidity of air were performed at a height of 1.5 m. For measuring was used the Rotronic HygroPalm psychrometer (wet-and-dry-bulb thermometer) with the HygroClip2 HC2-S3 sensor. It was also specified the degree of cloudiness.

4. Results and discussion

4.1. The results of the direct impact of the technological objects

The effect of the analyses was to determine the type, intensity and extent of the impact of the emission of odoriferous substances from objects identified as sources of air pollution by odorants. It was found that the air flowing into the sewage treatment plant is clean in terms of smell. During the research, the basic sources of odour nuisance were identified and their impact before and after modernization was characterized. As a result of extensive research conducted in 2015 and 2016-2017, nine main sources of odour emission were identified in the treatment plant. The more important of which are: piles of dewatered sludge and a small heap of screenings at the solid waste storage yard and the sludge dewatering building. The results of the comparative assessment of all sources are presented in Figure 5. It presents the maximum values of odour concentrations on the leeward side of technological sources before and after the modernization of the treatment plant.
It results from numerous own research studies (Kulig, 2004), carried out in the area and around the WWTPs facilities that range of impact of these objects/facilities is usually limited to a few hundred meters. In Figure 6, the maximum range of impact of particular sources of odour nuisance is presented, which in the case of the piles of dewatered sludge can reach up to 580 m outside the treatment plant.
It was found that after the modernization a significant reduction of the odour concentration emitted from the sludge dewatering building and sludge containers was obtained. Thanks to encapsulation of the sewer (covering with concrete slabs and sealing) a significant reduction in the odour concentration emitted from this source has been obtained. Figure 7 shows the spatial distribution of receptor points and the obtained results of the determination of the odour concentration in the period before the investment. Similar data for the period after technological changes are presented in Figure 8.

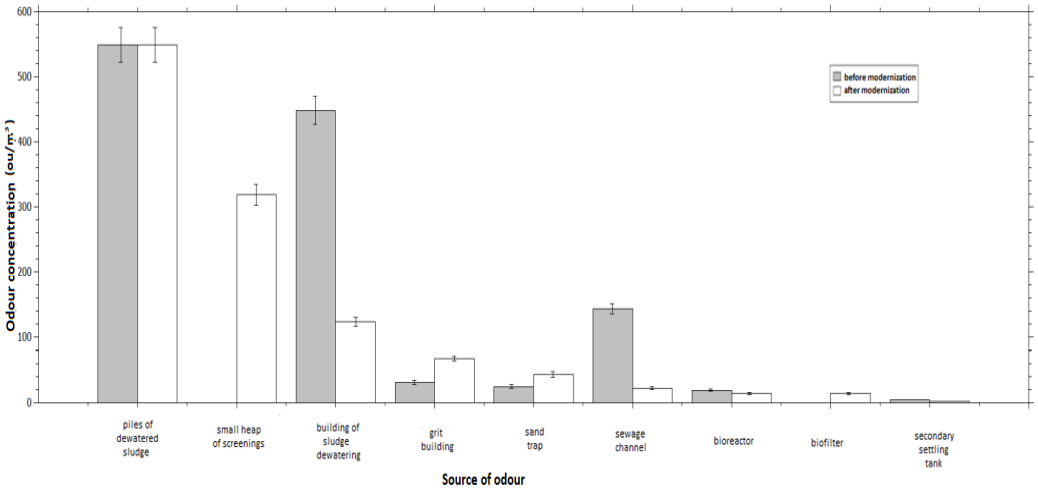


Figure 5. Maximum odour concentrations on the leeward side of the objects (depending on the potential source) – before and after the WWTP modernization

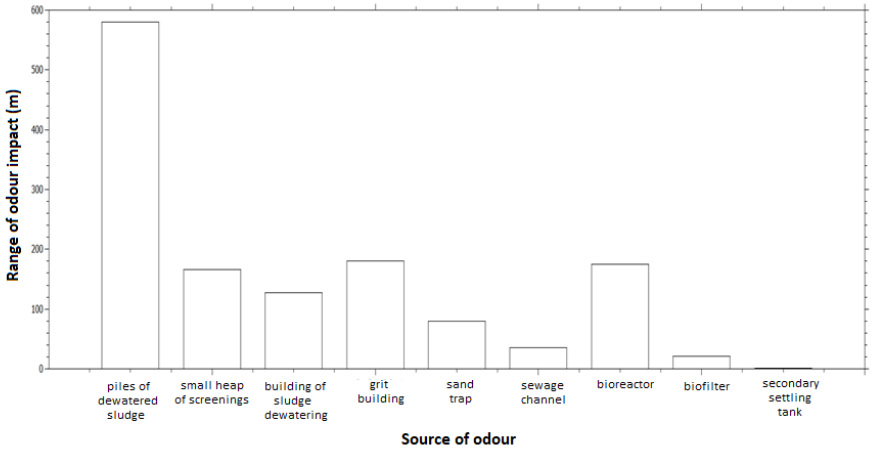


Figure 6. The maximum range of the odour impact of technological emission sources

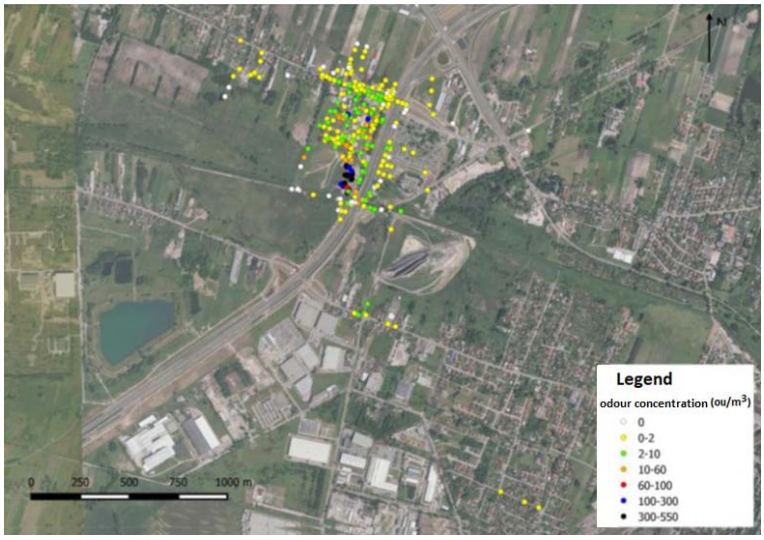


Figure 7. The spatial distribution of the odour concentration during the tests in 1-10 series – before modernization of the WWTP

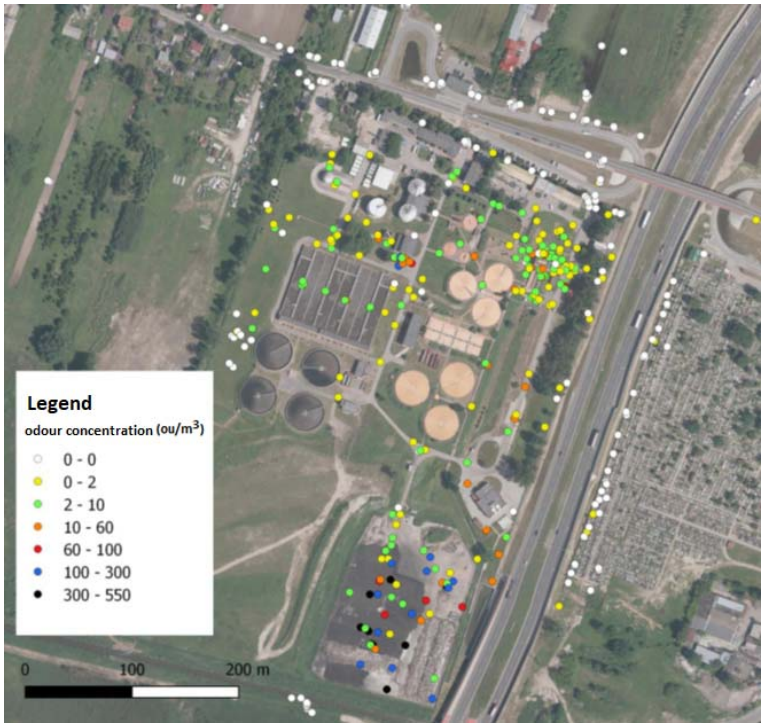
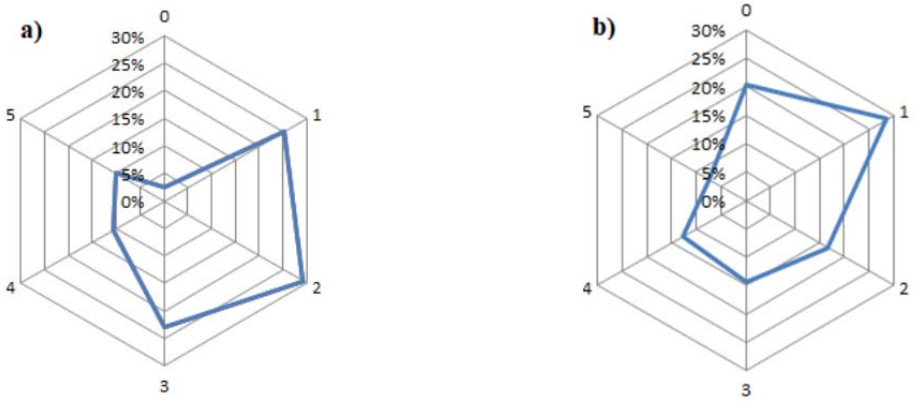


Figure 8. The spatial distribution of the odour concentration during the tests in 1-12 series – after modernization of the WWTP

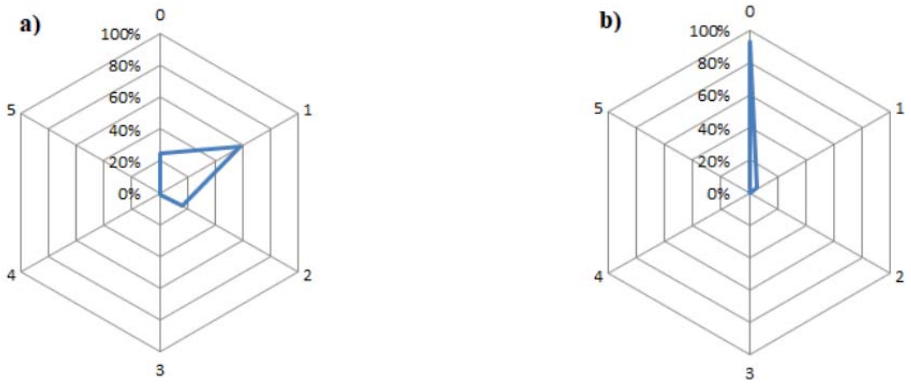
4.2. Final comparisons of the odour impact of WWTP

The results presented in the radar charts show changes in the percentage distribution of the frequency of occurrence of odour intensity values at the receptor sites in and outside the area of WWTP. In Figure 9 and 10 are shown comparison of the odour impact of WWTP before (a) and after (b) its modernization and expansion. It has been proven that the main source of odour nuisance is solid waste (in particular: sewage sludge) stored on an emergency waste storage yard. These wastes, even after modernization, were emitters of arduous, odorous compounds spreading out of the treatment plant. Despite this, as a result of the investment, the desired effect was achieved, which reduced the degree of odour nuisance.



before modernization – in 2015 after modernization – in 2016-2017

Figure 9. The percentage frequency distribution of occurrence of odour intensity values in wastewater treatment plant area



before modernization – in 2015 after modernization – in 2016-2017

Figure 10. The percentage frequency distribution of occurrence of odour intensity values outside wastewater treatment plant area

5. Conclusions

As a result, of the odorimetric research, comparison and final assessments carried out in the conditions before and after modernization of WWTP, taking into account the changing of technical and technological solutions, it has been found that:

1. The air flowing into the area of the tested WWTP is clean in terms of smell. The level of the so-called the background for the intensity and concentration of the aroma is zero. This means that there are no (no identified) sources of odorant emission, the impact of which would overlap the impact of the tested objects.
2. In the sewage treatment plant, the intensity of the smell changes in the full range (from i = 0 to i = 5), and the concentration of the odour from 0 to 549 ou/m^3.
3. Sources emitting a nuisance odour with a maximum concentration value of 549 ou/m^3 are piles of dewatered sludge located on the waste storage yard.
4. In three series of twelve olfactometric tests of air quality, odour effects were found outside the treatment plant. In these cases, there was a smell of screenings from the building of grates and a small heap of screenings, as well as the smell of dehydrated sludge from piles deposited on the sludge storage yard.
5. The maximum range of impact of the treatment plant was detected up to a distance of 580 m from the leeward side of the fence of WWTP installation, and the maximum value of the odour concentration, recorded off its area, 3 ou/m^3.
6. Modernization and extension of the technological instalations of biological reactors and secondary settling tanks did not affect the emission of odorous compounds from these facilities.

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Legal acts

[1] The Act of 27th April 2001 - *Environmental Protection Law* (Journal of Laws No. 62, item 627 as amended).

[2] The Act of 3th October 2008 *on provision of information on the environment and its protection, public participation in environmental protection and environmental impact assessment* (Journal of Laws No. 199, item 1227 as amended).

[3] The Regulation of the Council of Ministers of 9th November 2010 *on types of projects likely to have significant effects on the environment* (Journal of Laws No.213, item 1397).