Application of Dynamic Olfactometry
to Determine Odor Concentrations in Ambient Air

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Abstract

Our article deals with the problem of unpleasant odors, which in recent years have become increasingly acute. In this paper describes Vilnius wastewater treatment facilities located near residential districts of Vilnius, such as Karoliniškės and Lazdynai. The article deals with odor dispersion and its dependence on distance to the source, wind direction, speed, etc. Studies were carried out in three stages: Exploring the Vilnius District wastewater treatment plant (Gariūnai, Maxima bazė, supermarket Karoliniškės, and Lazdynai) and investigating wastewater treatment plant access (up to 1,000 m from the treatment plant), and a third installment fully investigated odor dispersion in the Lazdynai District. Studies have shown that under certain weather conditions (favorable winds, high wind speed, high air temperature) odor dispersion, and intensification that has exceeded Hygiene Norm HN 121:2010, "odor threshold concentration of the living environment in the air," to the specified maximum value.

Introduction

Odor problems have become more acute both in Lithuania and worldwide. Mostly people living near wastewater treatment plants, stalls, livestock farms, refineries, and other industrial objects complain about the unpleasant odors. Typically odors are not directly harmful to human health, because the problem of odor, in itself, starts at very low concentrations of chemicals. At present odor quality of the air, comprised of mixtures of many pollutants (very often not identified), can be determined only on the basis of olfactory signals analysis – thanks to biological and artificial noses [1].

Even if all over the world it is being recognized that odor affects only the emotional state of a person and there is no danger to health, odors, one way or another, have a negative impact on human activity [2].

Such contamination effects may include: environmental degradation; negative impact on property, plants, and ani-

mals; disruption of pleasant use of property; and impact on human well-being [3].

Odors can cause loss of appetite, water consumption decrease, breathing difficulties, nausea, and anxiety, not to mention a bad mood [4].

Wastewater treatment plants can be a source of unpleasant odors, especially during the anaerobic process (or processes within the low oxygen content) and in weather conditions favorable to odor formation (high relative environment humidity, average air temperature).

Such weather conditions may affect the formation of aromatic compounds (ammonium amines, mercaptans, organic acids etc.) which can have serious effects when it is not possible to ensure the proper distance between the source and residential areas, as often happens in densely populated areas [5].

During the decomposition of organic substances, malodorous gases are released (NH_3, H_2S, etc.). Biodegradation processes take place both in natural and artificial ways – during composting [6].

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Wastewater treatment plant odors can lead to sharp social and economic conflicts due to life quality decrease and the neighboring real estate prices fall, although they cause neither acute nor chronic health problems [2].

While combating odors in order to minimize their impact it is very important to keep the distance between the odor source (WWTP) and residential neighborhoods. There are two different ways of determining a safe distance: the first – recommendatory, the second – simulation. In most cases, the recommendation structure in different countries is similar [7].

Currently, the largest and the most important odor problem arises in Vilnius where, tired of the very unpleasant odor, the residents of Lazdynai and other neighborhoods complain and seek the intercession of various authorities. The problem is caused by the Vilnius wastewater treatment plant, where the wastewaters of Vilnius city and the settlements of Grigiškės, Daniliškės, and Baltoji Vokė are treated [8].

Treatment of wastewater and sludge treatment is distinguished by the entire bouquet of odors released by flavoring gases, which are often harmful to health. The person sensing an unpleasant odor cannot distinguish and identify what kind of gas it is, because, as mentioned, the odor is a mixture of many gases. Perhaps the main source of odor is hydrogen sulfide (H_2S) [9].

The aim of this work is to determine odor dispersion characteristics of Vilnius wastewater treatment plant (WWTP), to analyze the dependence on weather conditions – wind direction, speed, air temperature.

Methodology

In order to evaluate the odor concentration, in this work we used the dynamic olfactometry method. Dynamic olfactometry is a technique based on the sensory odor evaluation method that allows us to determine the concentration of odor through the evaluation team. Odor concentration is expressed in European odor units per cubic meter of air [OUE/m^3], and it shows the number of dilutions required to make the sample concentration equal to the concentration of smell [10].

An olfactometer is a device that dilutes the sample of the odor polluted air in certain proportions and submits them for the evaluators to smell. The sample is diluted and given to the evaluators to smell, until the evaluators smell the odor. At first, the degree of dilution is very high – many evaluators do not perceive the odor, then the sample is diluted at a lower ratio, and so on, until all the evaluators feel the odor and are sure that they smell it. In this work, we used the olfactometer AC'SCENT®.

The olfactometer AC'SCENT® allows few different analysis methods: the forced choice method, yes/no method, and the direct application method.

In our analysis we used a forced choice method, in which each evaluator receives three sniffing air samples (three for each degree of dilution), one of which is the pol-

luted air, and the other two are "empty." Then, the evaluator must decide which one is different. With a choice he must comment on his choice – whether he guesses, or he felt the difference, is he totally sure, that he feels the odor.

If one or more individual threshold values do not satisfy ΔZ criterion, then all responses given by the panel member with an inadequate ΔZ must be eliminated by the final result and the procedure is repeated until all data provided by panel members are consistent with the criterion. The ΔZ parameter indicates the coherence of panel members' responses and puts in evidence the gaps eventually present compared to the mean (EN 13725:2003). Later, concentration shall be deducted from the answers of evaluators. Separate sample tests shall be repeated three times. The study involved six assessors, aged 24 to 30 years.

For the environmental air and experimental research it is necessary to collect air samples. Air samples are taken with vacuum chambers and placed in "Tedlar" bags. This is the world's most popular and most commonly used air sampling method.

For air sampling the "lung principle" is used, where the sample bag is placed in a rigid container, the air from the container is removed with a vacuum pump, and due to the low pressure in the container the bag fills it with a sample content at the level of the air removed from the container.

Samples are analyzed as soon as possible after sampling. The time interval between sampling and measuring should be no longer than 30 hours.

Available and in-use European standards describe the methods and conditions of measuring odour concentration in the vicinity of the selected emission sources [11].

Vilnius wastewater treatment plant capacity is 225,000 m^3 per day. In this treatment plant, during the year, 42 million m^3 of wastewater is cleaned. The company supplies drinking water, and collects and cleans the wastewater of 589.900 users. The company supplies 103.900 m^3 of water per day and collects and purifies 115.500 m^3 of wastewater per day. The Vilnius sewage piping network is about 1,125 km. Water quality checks and controls drinking water laboratory and purified sewage – sewage laboratory. The company provides services to 18,131 objects.

Vilnius wastewater treatment plant neighborhood air pollution with odor was studied in three stages. In the first stage the area near the treatment plant was investigated, in the second – the area of residential neighborhoods closest to the plant, in the third a more detailed study of Lazdynai residential neighborhood. The first stage aims to determine the odor concentration dependence of the distance from the wastewater treatment plant to the distance from the plant, where the odor concentration would not exceed the permissible limits – 8 OUE/m^3. The second stage aims to measure the odor concentration near the residential and commercial neighborhoods and to find out in which cases the complaints of the residents are justified, and when not. And the third stage aims to determine how odor concentration is distributed "inside" the Lazdynai neighborhood.

In the territory of the plant 12 samples were taken. The prevailing wind rose (Fig. 1) shows that in Vilnius district
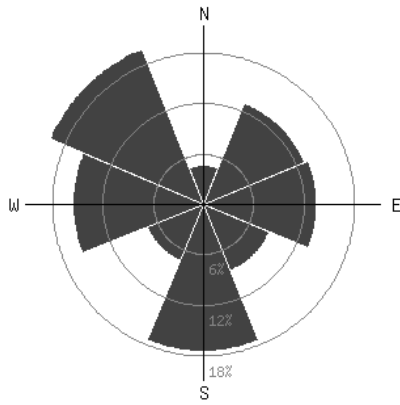
Fig. 1. Vilnius wind rose.

the south, northwest wind prevails. At different distances from the plant three samples are taken downwind, i.e. to the south and southeast of the treatment plant. Also, for comparison three samples in the different distances are taken not downwind, i.e. to the east of the treatment plant. All points are shown in Fig. 2. In the second stage of the work the surroundings of the residential neighborhood are investigated. This study aims to measure the odor concentration, the source of which is Vilnius wastewater treatment plant. Air samples are taken in different weather conditions (wind speed and direction). Four air samples are taken in these residential areas or commercial areas that are the closest to the wastewater treatment plant. The sampling points are shown in Fig. 3.
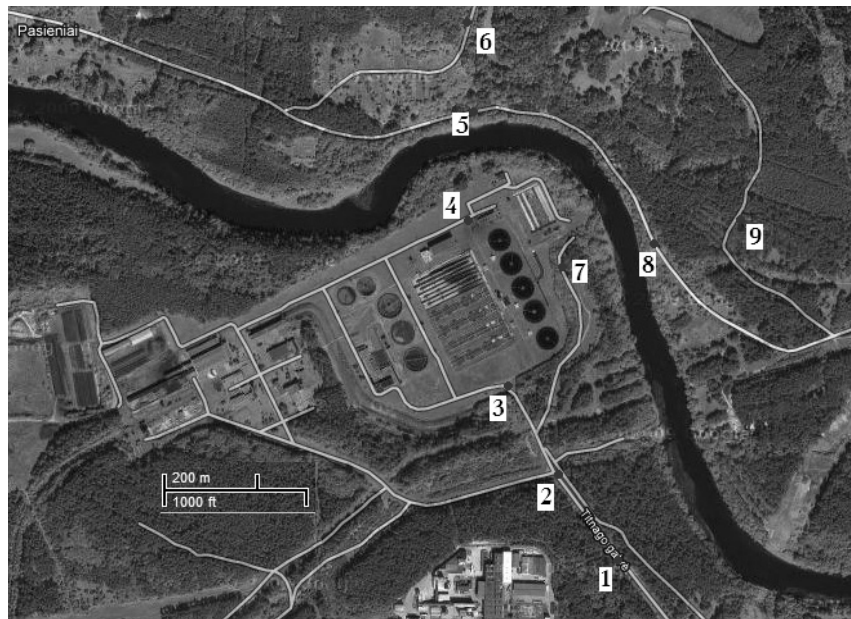

Fig. 2. Vilnius WWTP and sampling sites. Sampling site distances to Vilnius WWTP: 1 – south 500 m; 2 – south 250 m; 3 and 4 – south 0 m; 5 – north 250 m; 6 – north 400; 7 – northeast 0 m; 8 – northeast 250 m; 9 – northeast 450 m.
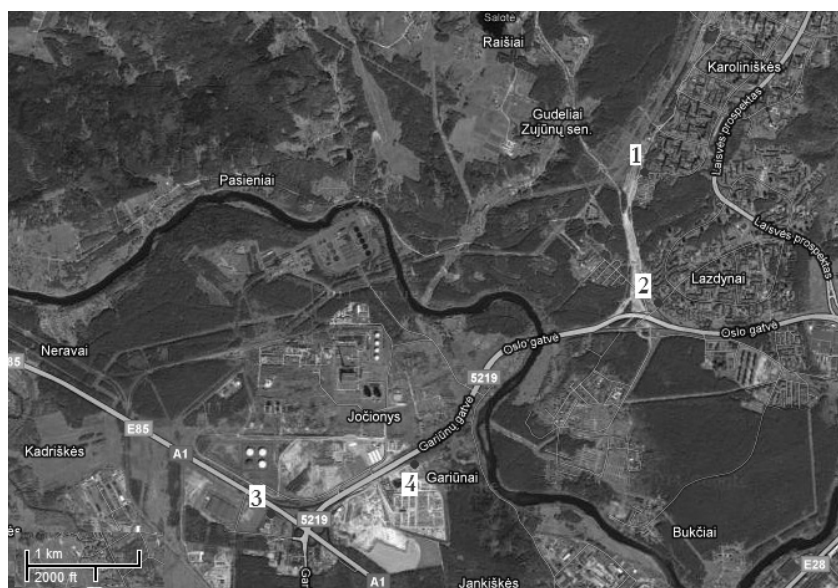

Fig. 3. Sampling sites around Vilnius WWTP. Sampling site distances to Vilnius WWTP: 1 – east 2.7 m, neighborhood Karoliniškės, L.Asanavičiūtės st.; 2 – east 2.7 m, neighborhood Lazdynai, Erfurto st.; 3 – south 2.3 m, Market "MAXIMA bazė," Pirklių st.; 4 – south 2.0 m, Market "Gariūnai."

Fig. 4. Sampling sites in Lazdynai. Sampling site distances to the Vilnius WWTP: 1 – 2,500 m; 2 – 2,800 m; 3 – 3,100 m; 4 – 3,400 m; 5 – 3,700 m.

At these points the samples were taken twice, with different directions of wind. The first time odor concentration was measured with a 9 m/s southwest wind. The second measurement was carried out with a 2 m/s northwest wind.

In the third stage the odor concentration was measured in Lazdynai neighborhood. The measurements were carried out at five different points (Fig. 4). Points are at different distances from the odor source (Vilnius wastewater treatment plant); the distances are shown in Fig. 4. During the sample a 6 m/s southwest wind was blowing.

The results section presents the two odor concentration values – odor detection threshold in parentheses with the letter "D" (detection), and odor recognition threshold in parentheses with the letter "R" (recognition). Hygiene Norm HN 121:2010, "Odor concentration threshold in the air of living environment," provided odor concentration values to meet our used (R) value, when the odor concentration measured, when the evaluator claims he is sure to feel the odor. Odor sensing threshold (D) is calculated by using the evaluator answers that he submitted only guessing that he feels the odor. (D) value in this article is given for comparison.

Hygiene Norm HN 121:2008, "Odor concentration limits in residential and public buildings and their plots," determines odor concentration limit values and techniques for residential and public buildings and land. This HN is subject to and binding on all natural and legal persons who are pursuing or planning activities associated with these buildings, and institutions that carry out air pollution control, which may result in undesirable foreign odors. Odor threshold values in residential and public buildings in this document are in European odor units [OUE/m^3]. Odor concentration in the latest buildings or sites assessed by the measurement results by comparing them with normative thresholds. Maximum value is 8 OUE/m^3.

Results and Analysis

The analyses were conducted in natural conditions, the all air sampling time, with air temperature between 5 and 18ºC, wind speeds from 1 to 9 m/s. After the measurement of odor concentration in 1, 2, and 3 points (Fig. 2) near Vilnius wastewater treatment plant, the following results were obtained (Fig. 5): near the wastewater treatment plant 43 (D) and 31 (R) OUE/m^3 odor concentration was observed, and within 300 m – 23 (D) and 11 (R) OUE/m^3. Within 500 m from the wastewater treatment plant the odor does not exceed the permitted norms and its concentration is as low as 11 (D) and 6 (R) OUE/m^3. With such air conditions Vilnius wastewater treatment plant does not violate the requirements of hygiene norms and does not cause discomfort of residents. The air temperature during the sampling was 18ºC, and a 1.5 m/s north wind was blowing.

In the similar weather conditions (air temperature 15ºC, west wind 1 m/s) the odor concentration in the surrounding air was measured. The samples were taken in the opposite direction from the wastewater treatment plant
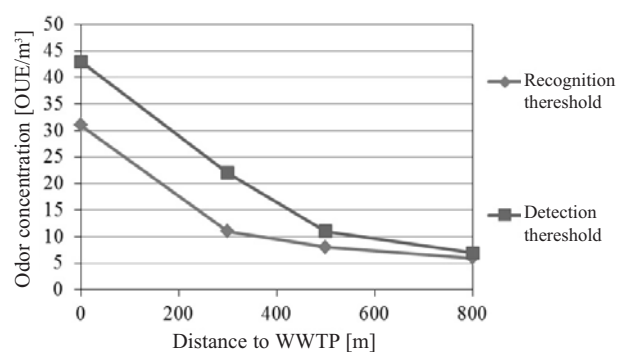

Fig. 5. Odor concentration dependence of the distance in points 1, 2, 3.

(points 4, 5, 6, in Fig. 2), but the distances remained close to the samples taken before.

In this case, a little bit higher odor concentration is traced (Fig. 6). It was influenced by wind direction, which in this case was favorable to odor dissemination. Although the wind was not strong, the distance to the threshold (when the odor concentration is not exceeding the permitted norms) increases. In this case, within 650 m, 10 (D) and 7 (R) OUE/m³ odor concentration is recorded.

Near the wastewater treatment plant the odor concentration reaches 65 (D) and 46 (R) OUE/m³, which is slightly more that the concentration on the other side of the wastewater treatment plant area in similar weather conditions. Within 250 m from the plant, 43 (D) and 32 (R) OUE/m³ concentrations are recorded, and within 400 m in the same direction – 18 (D) and 11 (R) OUE/m³.

Measured odor concentrations are at the points located to the east from the wastewater treatment plant (Fig. 2). The measurements were carried out with 3 m/s northwest wind blowing (air temperature 5ºC), which, in this case, was in favor of odor spread to the east. At the seventh point, which is near the wastewater treatment systems, measured odor concentrations reached 60 (D) and 44 (R) OUE/m³. This is a low odor concentration compared to the previous measurements, and this was influenced by low ambient temperature. Moving away from the odor source, the odor concentration in ambient air decreases (Fig. 7), within 500 m 23 (D) and 19 (R) OUE/m³ are recorded, and within 800 m – accordingly 16 and 11 OUE/m³ odor concentrations. The odor concentration reaches a value not exceeding the permitted
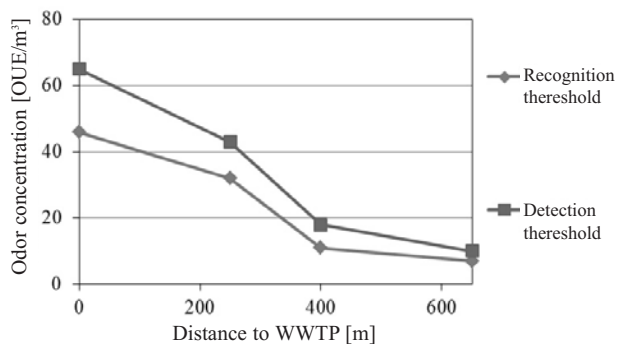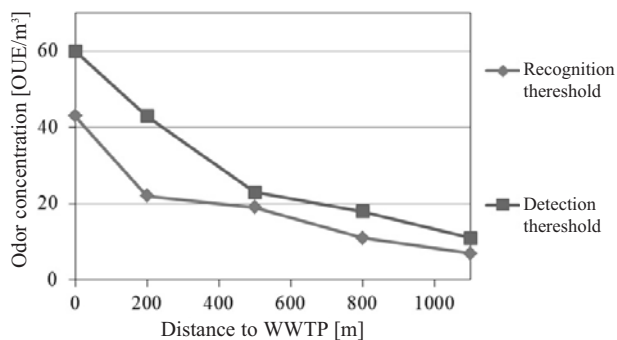
norms within 1100 m from the wastewater treatment plant. The distance to the point where the odor concentration does not exceed the norms is bigger than that measured in other directions in other weather conditions, in my opinion, due to the favorable wind direction and higher wind speed.

During the odor measurements at four points near the residential and commercial areas the following results were received (Fig. 8): with an unfavorable 2 m/s southwest wind blowing, the odor was recorded only at the 4th point (Fig. 3) and the odor concentration was only 7 OUE/m³ (D). In these weather conditions at the third point the odor was not recorded. This concentration does not exceed any normative values. This is influenced by the weak, unfavorable wind direction. With 9 m/s southwest wind blowing the situation is totally different. Due to considerable speed and wind direction favorable to dissemination, big odor concentrations were recorded at the 1st 51 OUE/m³ (R) and the 2nd point 61 OUE/m³ (R) (Fig. 3). These odor concentrations have exceeded the permitted norm several times. HN 121:2010 "Odor concentration threshold in the air of living environment" provides the maximum permitted odor concentration threshold in the air of living environment, and it is 8 European odor units (8 OUE/m³). Summarizing these two measurements, it can be said that the biggest influence to odor dissemination is wind direction and, in certain weather conditions, the odor concentration exceeds the permissible value.

The third stage studied odor dispersion in Lazdynai neighborhood, where a wind blew air masses directly from the wastewater plant. During the analysis, a 6 m/s southwest wind was blowing, and the air temperature reached 12ºC. At the first point on the outskirts of Lazdynai neighborhood, which is the nearest to the wastewater treatment plant, during the analysis a big odor concentration was noted (83 (D) and 60 (R)), which far exceeds the standard of hygiene. Furthermore, the odor concentration decreases (Fig. 9); at the second point, accordingly, 60 and 31 OUE/m³ was recorded. Thus moving away from the wastewater treatment plant the odor concentration decreases, while on the outskirts of the neighborhood, within 3,700 m of the wastewater treatment plant, the odor concentration decreases to permissible values – 7 OUE/m³.

Until the first point the air masses from the wastewater treatment plant move in open space, and high odor concentrations reach the neighborhood. On the outskirts of

Fig. 6. Odor concentration dependence on distance at points 4, 5, 6.

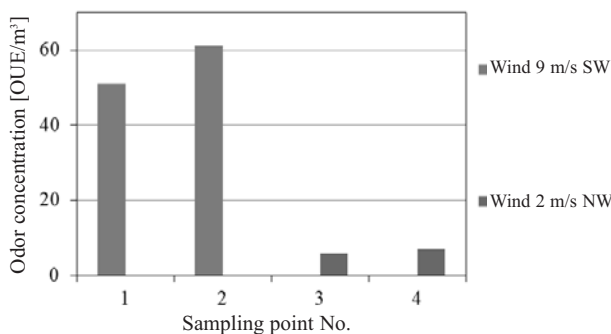Fig. 7. Odor concentration dependence on distance at points 7, 8, 9.

Fig. 8. Odor concentration measured by the characteristic points of the Vilnius district wastewater treatment plant.
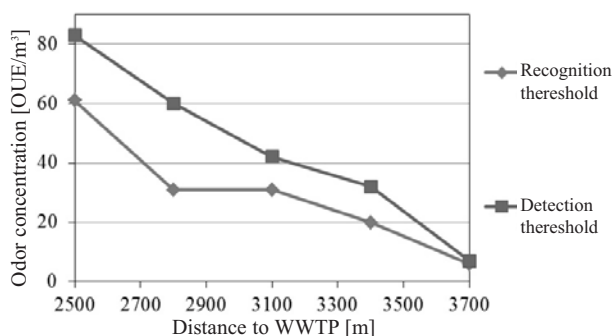
Fig. 9. Odor concentration dependence of the distance in Lazdynai (points 1, 2, 3, 4, 5 in Fig. 4).

Lazdynai the air masses do not have an avenue for free movement, and the odor concentration decreases until it reaches the permissible value. However, the bigger part of Lazdynai neighborhood in the said weather (significant south-west wind) feels an unpleasant odor, which exceeds the value of the hygiene standard.

Conclusions

1. The biggest recorded odor concentration in the air of living environment reaches 61 OUE/m³. This value exceeds the permissible standard 7.5 times.
2. Wind direction and speed has the biggest influence on odor dispersion. The concentration measured at the measurement point in Lazdynai neighborhood: 61 OUE/m³ with a favorable wind direction (southwest) and 6-7 OUE/m³ with an unfavorable wind (northwest).
3. In the case of the northwest wind, the odor does not reach Lazdynai neighborhood. In the case of the southwest wind (speed 6 m/s), 60 OUE/m³ odor concentration reaches Lazdynai neighborhood by reaching the permissible value only within 1,200 m of the first buildings.
4. In the case of 1-3 m/s wind, within 400-500 m from the wastewater treatment plant area, the odor concentration does not exceed the permissible value.

5. Odor concentration (D) value changes in the similar way as value (R). Both values change almost in a parallel way.

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