Substantiation of the permissible value of odor from sewerage system facilities

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Abstract. With the growth of urbanization in large cities, the number of complaints from the population on unpleasant odors emitted by sewerage system facilities increases. In most cases, instrumental measurements on the content of individual malodorous substances in the zone of influence of sewerage facilities do not confirm the exceeding of the atmospheric air quality standards, even in terms of unpleasant odor. The lack of a clear system for standardizing odor in the atmospheric air and of established odor standards in Russia determined the relevance of this study. The aim of the study is to substantiate the permissible value of the odor emitted by sewerage system facilities. The article describes the research methodology. The results of field studies on the content of pollutants in the atmospheric air and the concentration of odor at the border of the sanitary protection zone of sewerage facilities are presented. The criteria for odor evaluation are proposed. The permissible value of odor for sewerage facilities is substantiated.

Key words: malodorous substances, odor standard, sanitary-hygienic standards, olfactometric studies, sewerage system facilities, odor control

1. Introduction

Sewerage system facilities, generated as a result of the vital activity of the population, are an obligatory attribute of big cities. In the process of sewage, the gas, saturated with malodorous substances [1,2], is released. In places where sewerage network structures exit to the day surface, emissions of malodorous gas into the atmosphere cause discomfort in urbanized areas [3,4]. The number of complaints from the population on unpleasant odors increases. Instrumental measurements of the content of individual malodorous substances in the zone of influence of sewerage system facilities, as a rule, do not confirm the exceeding of the atmospheric air quality standards, even in terms of unpleasant odor.

The Russian legislation has not yet established the odor standards in the atmospheric air. Therefore, there are no legitimate levers of influencing enterprises, which are the sources of unpleasant odors.

In the international practice, the US standard ASTM E 679-04 [5] and the European Standard EN 13725 [6] are the most widely used standards to measure the odor concentration values with the help of equipment, experts, and statistical methods. There are atmospheric air quality standards for the odor of a number of odorous compounds (such as ammonia and hydrogen sulfide).

Standardized values of the odor emissions significantly differ in various countries and amount to: 1-7 ouE in Canada; 8-25 D/T in the USA; 10-25 ouE in South Korea; 0.5-10 ouE in Australia; 1-10 ouE in New Zealand; and 1-5 ouE in Europe. Meanwhiles, the minimum values as a rule are set for
residential areas, and the maximum ones for industrial areas. The research studies conducted abroad have shown that 10% of the surveyed population experience the significant “irritation” at an estimated exposure level of 5 ouE/m³, and in cases of some odors: at a level from 1.5 ouE/m³ (treatment facilities, oil refineries) to 3 ouE/m³ (pig farms, sugar production) [7].

In Russia, the odor control is managed on the basis of sanitary-hygienic regulations and olfactometry.

In the field of sanitary-hygienic regulation, the presence of odor in the air has always been a hazard limiting index when substantiating the maximum permissible concentration value (MPC) of substances in the atmospheric air [8, 9]. In the Russian Federation, for substances with odor, the maximum one-time (20–30-minute) MPCmo is set in the experiment based on the results for determining the odor threshold [10]. In this case, the concentration the probability of sensing which amounts to 16% is taken as the odor threshold [10,11]. The method of organoleptic control of pollutants has been supplemented by the odorimetric assessment of odor [12] with the use of a 6-point system for assessing its strength (intensity) [13]. Odorimetric criteria for assessing the odor, including its “persistence”, have been proposed [14-16]. However, in terms of the odor regulation in Russia, today the only applicable requirement of the federal sanitary-hygienic legislation in accordance with SanPiN 2.1.6.1032-01 is the non-exceeding of the amount of the MPCmo of pollutants, which is established to prevent the appearance of odors. There are no sanitary-hygienic odor standards in the Russian Federation.

In accordance with ITS-22-2016 [20], the best available technology in the field of preventing and reducing the generation of odors (BAT 5-1) implies the setting of an indicative level of the odor exposure for a specific residential area (odor standard). In Russia, GOST R 58578-2019 [21] regulates the procedure for establishing standards and control over odor emissions into the atmosphere using the method of dynamic olfactometry.

In response to complaints from the population on unpleasant odors, the olfactometric studies on controlling and standardizing odor emissions [17-29] in various regions of the Russian Federation have been fulfilled. Based on the research results, the suggestions on establishing the local / regional odor standard have been proposed. These suggestions have not been approved in any of the regions due to the lack of a regulatory framework. The suggestions on introducing the definition of “odor level” into the Federal Law “On the Protection of Atmospheric Air”, and on delegating responsibility to the regional level in the matter of odor regulation are being initiated.

The lack of a clear system for standardizing odor in the atmospheric air and established odor standards, allowing to substantiate, implement, and monitor the effectiveness of technical solutions in the field of preventing or reducing the odors for various types of industries, or certain enterprises and territories in Russia determines the relevance of this study.

2. Materials and research methods

The object of the study has been a section of the sewerage network in the central part of a city, where the residents periodically sensed unpleasant smells. The length of the section equaled 10.57 km.

The subject of the study has been the state of atmospheric air, the presence of odor near the following facilities of the sewerage network: district pumping stations (RNS), pressure damping chambers (KGN), sewer holes (KK), and wells. The sources of odor emissions at the district pumping stations were ventilation pipes, at the pressure damping chambers - leakiness in manholes, and in wells - treated emissions from ventilation cabins.

The aim of the work is to substantiate the permissible odor value from sewerage system facilities. To achieve the goal, the following tasks have been set and solved:

1. Obtaining objective instrumental data on the concentration of pollutants in the atmospheric air and the concentration of odor at the border of the sanitary protection zone (SPZ) of sewerage facilities at control points;
2. Development and justification of the criteria for evaluating the odor. Forming of the proposals on the permissible odor value.
The research studies have been conducted in accordance with the elaborated program, which included studying the state of the atmospheric air, odor concentration – 5 times a year: in winter, spring, summer (July, August), and autumn.

Within the frameworks of the research, field work (forming of an observation network, performing field measurements, as well as sampling for subsequent analysis); laboratory work (analyzes and studying of samples); and in-office work (processing, consolidation, and analysis of the field information) have been fulfilled.

Control ground points have been selected taking into account the actual wind direction. In all cases, samples have been taken from the leeward side at a specified distance from the source. The characteristics of sewerage facilities is given in Table 1. The actual meteorological parameters, such as temperature, pressure, wind direction, and wind speed, have been determined at the control points.

Table 1. Characteristics of sewerage facilities, control points.

| Control point No. | Name of facility | Characteristics of the emission source | Place of sampling |
|-------------------|------------------|----------------------------------------|-------------------|
| 1                 | RNS-1            | organized                              | at the border of the approved SPZ (30 m) |
| 2                 | KGN-1            | non-organized                          | at a distance of 20 m |
| 3                 | RNS-2            | organized                              | at the border of the approved SPZ (20 m) |
| 4                 | KGN-2            | non-organized                          | at a distance of 20 m |
| 5                 | RNS-3            | organized                              | at the border of the approved SPZ (30 m) |
| 6                 | KGN-3            | non-organized                          | at a distance of 20 m |
| 7                 | KK               | non-organized                          | at a distance of 20 m |
| 8                 | well No.1        | organized                              | at a distance of 20 m |
| 9                 | well No.2        | organized                              | at a distance of 20 m |

The samples of the atmospheric air have been analyzed for the concentrations of methane (PND F 13.1: 2: 3.27-99), hydrogen sulfide, and ammonia (RD 52.04.795-2014).

Odor concentration measurements are conducted simultaneously at the same control points where the atmospheric air samples are taken.

Field measurement of odor at control points is done using Nasal Ranger portable olfactometer. The operating principle of the portable olfactometer lies in mixing malodorous atmospheric air with filtered, non-polluted air. A panel of experts has been evaluating the presence of odor in samples, containing polluted air, which has been gradually mixed with purified air to a level at which the experts could not smell it. The device has been used to carry out several series of discrete dilutions of odor-polluted atmospheric air with clean air. Each level of discrete dilution is defined as a correlation of dilution to a threshold level (D/T). The graduated disc (D/T) of the olfactometer allows to perform discrete dilution to a threshold level where the contaminated, malodorous air sample is diluted 2, 4, 7, 15, 30 and 60 times.

Four experts (2 women and 2 men) aged 22–62, trained to operate an olfactometer, have participated in the study on the odor effects.

Odor intensity measurements and the measurement results processing have been performed in accordance with the requirements of GOST R 58578-2019 [21].

3. Results and discussion
Main substances, that are the sources of odor at sewerage facilities, are hydrogen sulfide (H2S), mercaptans, ammonia and volatile organic compounds. Table 2 presents a list and characteristics of the main malodorous substances.

As a result of studying the world practices and Russian practice, we tend to consider the following criteria for evaluating odor:
- Responding to complaints from the population;
- Complying with the hygienic standards for the quality of atmospheric air at the border of the sanitary protection zone (SPZ) of sewerage system facilities with a coverage of more than 90%;
- Monitoring the concentration of odor.

**Table 2.** Sanitary-hygienic standards, and odor threshold of the main malodorous substances.

| Substance             | MPC<sub>mo</sub>, mg/m<sup>3</sup> | Hazard limiting index | Hazard class | PD<sub>ss</sub>, mg/m<sup>3</sup> | Odor threshold, mg/m<sup>3</sup> |
|-----------------------|---------------------------------|-----------------------|--------------|---------------------------------|-----------------------------------|
| Hydrogen sulfide      | 0.008                           | reflex                | 2            | -                               | 0.014-0.03 – threshold            |
|                       |                                 |                       |              |                                 | 1.4–2.3 – perceptible             |
|                       |                                 |                       |              |                                 | 4 – considerable                 |
|                       |                                 |                       |              |                                 | 7-8 – heavy                       |
| Ammonia               | 0.2                             | reflex-resorptive     | 4            | 0.04                            | 0.5 – threshold                   |
|                       |                                 |                       |              |                                 | 2–32 – perceptible                |
| Methane               | 50 (SRLI)                       | -                     | -            | -                               | non-odorous                       |

The results of the research studies on the concentration of pollutants in the atmospheric air at the border of the sanitary protection zone of sewerage facilities during the year have shown no exceeding in the MPC<sub>mo</sub> for ammonia and methane at all control points. Methane is non-odorous. The odor threshold for ammonia is higher than the recorded concentration of ammonia in the atmospheric air in the control points’ influence zone. The hedonic tone of odor determined during the field work has, in all cases, been classified as hydrogen-sulfide-like. Therefore, it has been decided not to consider the effect of ammonia and methane on odor, but to correlate the presence of odor with the priority pollutant - hydrogen sulfide.

Quantitative research results are shown in Table 3. Over the monitoring period, 45 samples of the atmospheric air and 45 samples of odor have been examined. The total number of samples exceeding the MPC<sub>mo</sub> for hydrogen sulfide amounted to 4 samples (9%), and the number of samples exceeding the H<sub>2</sub>S odor threshold (> 0.014 mg/m<sup>3</sup>) amounted to 2 samples (4.5%).

**Table 3.** Research results on the concentration of hydrogen sulfide and the concentration of odor in the atmospheric air in the zone of influence of sewerage facilities

| Control point No. | Name of facility | Concentration of hydrogen sulfide in the atmospheric air, mg/m<sup>3</sup> | Concentration of odor, D/T |
|-------------------|------------------|-----------------------------------------------------------------------------|---------------------------|
|                   |                  | Temperature °C / wind speed, m/s                                              |                           |
|                   |                  | July 2019                      | August 2019                | October 2019               | January 2020                      | March 2020                      | July 2019 | August 2019 | October 2019 | January 2020 | March 2020 |
| 1                  | RNS-1            | <0.006                         | <0.006                      | <0.006                      | <0.006                           | 0                         | 0                 | 0            | 0            | 0            |
|                   |                  | 20/1.5                         | 15/1.0                      | 4/1.0                       | -3/1.5                           | 0.5/1.3                      | 0                 | 0            | 0            | 0            |
| 2                  | KGN-1            | <0.006                         | <0.006                      | <0.006                      | <0.006                           | 2                         | 2                 | 0            | 0            | 0            |
|                   |                  | 21/1.9                         | 15/1.0                      | 4/1.8                       | -2/1.4                           | 0.5/1.3                      | 2                 | 0            | 0            | 2            |
| 3                  | RNS-2            | <0.006                         | <0.006                      | <0.006                      | <0.006                           | 0                         | 0                 | 0            | 0            | 2            |
|                   |                  | 19/1.5                         | 15/1.0                      | 2/1.3                       | -3/1.0                           | 1/1.2                       | 2                 | 0            | 0            | 2            |
| 4                  | KGN-2            | <0.006                         | <0.006                      | <0.006                      | <0.006                           | 2                         | 0                 | >60<sup>a</sup> | 7<sup>a</sup> | 2            |
|                   |                  | 19/1.1                         | 15/1.0                      | 2/1.1                       | -3/1.5                           | 0.5/1.0                      | 0                 | 0            | 0            | 0            |
| 5                  | RNS-3            | <0.006                         | <0.006                      | <0.006                      | <0.006                           | 2                         | 0                 | 0            | 0            | 0            |
|                   |                  | 22/1.5                         | 16/1.9                      | 4/1.4                       | -2/2.3                           | 0.5/1.7                      | 0                 | 0            | 0            | 0            |
| 6                  | KGN-3            | <0.006                         | <0.006                      | <0.006                      | <0.006                           | 0                         | 0                 | 0            | 0            | 0            |
|                   |                  | 24/1.3                         | 16/2.6                      | 5/1.6                       | -1/1.0                           | 0.5/1.2                      | 0                 | 0            | 0            | 0            |
| 7                  | KK               | <0.006                         | <0.006                      | <0.006                      | <0.006                           | 2                         | 0                 | 0            | 0            | 0            |
|                   |                  | 24/1.5                         | 16/1.0                      | 5/1.9                       | -1/1.3                           | 0/1.2                        | 0                 | 0            | 0            | 0            |
The odor concentration at control points has ranged in the interval of 0-2 D/T on the olfactometer scale.

The correlation of concentration of hydrogen sulfide in the atmospheric air and the concentration of odor with the actual meteorological parameters has not been found.

The comparison of the concentration of hydrogen sulfide in the atmospheric air and the concentration of odor at the border of the zone of influence of control points has shown that the 2 D/T odor concentration in 91% of cases provides a sanitary-hygienic standard for the quality of atmospheric air as per hydrogen sulfide <0.008 mg/m³.

Based on the results of the studies, it is proposed to take the value of 2 D/T as the permissible value of odor from sewerage system facilities.

4. Conclusion

The proposed permissible value of odor from sewerage system facilities equal to 2 D/T:
- is determined on the basis of field studies during one year (all seasons);
- considers objective quantitative data, both on the concentration of the priority pollutant, hydrogen sulfide, and the concentration of odor;
- takes into account both the hygienic standard (MPCmo) of hydrogen sulfide and the rules for establishing standards on the emission of odor into the atmosphere;
- in 91% of cases ensures the observance of the sanitary-hygienic standard for the atmospheric air quality for hydrogen sulfide <0.008 mg/m³.

The presented odor standard from sewerage system facilities ensures a sufficiently high reliability of compliance with the atmospheric air quality standard for hydrogen sulfide, as well as simplicity and availability of odor control and the ability to evaluate the effectiveness of measures to reduce emissions of malodorous substances at sewerage facilities.

References

[1] Gutierrez O, Sudarjanto G, Ren G, Ganigué R, Jiang G and Yuan Zh 2014 Assessment of pH shock as a method for controlling sulfide and methane formation in pressure main sewer systems *Water research* 48 569–578

[2] Gerars M N 1982 A review of dangerous gases in sanitary sewers Public Works 113(10) 34–36

[3] Vasiliev V M and Malkov A V 2016 Gases in Sewerage Networks, Hazard Caused by Them, and Ways of Its Elimination Engineering and Technology of the World 3-4 (81-82) 48–53

[4] Rublevskaya O N 2013 Measures on preventing malodors release at the facilities of SUE “Vodokanal of St. Petersburg” Water Supply and Sanitary Technique 10 46–55

[5] 2004 ASTM E679-91. Standard Practice for Determination of Odor and Taste Threshold by a Forced-Choice Ascending Concentration Series Method of Limits American Society of Testing and Materials (Philadelphia: PA) p 7

[6] European Standard "CEN (2003) Air quality – Determination of odour concentration by dynamic olfactometry. EN 13725:2003", European Committee for Standardization

[7] Loriato A G, Salvador N, Santos J M, Moreira D M and Reis N C 2012 Smell-overview of existing regulation Chemical Engineering Transactions 30

[8] GN 2.1.6.1338–03 2003 Maximum Permissible Concentrations (MPC) of Pollutants in the Atmospheric Air of Populated Areas (Moscow: MZ RF)
[9] Pinigin M A 1993 Hygienic Bases for Evaluating the Degree of Air Pollution *Hygiene and Sanitation* **7**, 4–8

[10] 1989 Temporary Guidelines for Substantiating Maximum Permissible Concentrations (MPC) of Pollutants in the Atmospheric Air of Populated Areas, No. 4681-88, MZ SSSR (Moscow)

[11] Andrescheva N G and Pinigin M A 1978 *Hygienic Aspects of Environmental Protection* (Moscow: IOKG im. A.N. Sysina) **6**, 75–76

[12] Budarina O V, Pinigin M A, Fedotova L A, Sabirova Z F and Potapchenko T D 2017 Modern Methodological Approaches to the Experimental Substantiation of the Permissible Content of Odorous Substances in the Ambient Air *Toxicological Review* **4**, 34–39

[13] Pinigin M A, Budarina O V and Safiulin A A 2012 The Development of Hygienic Basis of Odour Regulation and Control in Ambient Air and Ways of Harmonization in This Field *Hygiene and Sanitation* **5**, 72–75

[14] Baeva I V 2007 Hygienic Assessment of the Tobacco Enterprise in Yaroslavl as a Source of the Atmospheric Air Pollution: Abstract of a thesis...Candidate of Sciences (Medicine) (Moscow)

[15] Pinigin M A, Budarina O V et al. 2003 *Theoretical Foundations and Practical Solutions to the Problems of Sanitary Protection of the Atmospheric Air* (Moscow) pp 228–230

[16] Ingel F I, Budarina O V, Akhaltseva L V and Yudin S M 2018 Impact of Odour Emissions on Human Overall Health, Activity and Mood *International Journal of Applied and Fundamental Research* **10**, 64–68

[17] Yatsenko-Khmelevskaya M A, Tsibulski V V, Khitrina N G and Korolenko L I 2013 Olfactometric investigations of odor emissions by industrial enterprises in Russia. *Biosphera Interdisciplinary Journal Basic and Applied, Sciences* **5**(3), 303–310

[18] Tsibulski V V, Yatsenko-Khmelevskaya M A, Khitrina N G and Korolenko L I 2011 Investigation of Odor at Treatment Facilities *Industrial Ecology* **4**, 52–56

[19] Chepegin I V and Andriyashina T V 2013 Emissions of odorous substances into the atmosphere. Problems and solutions *Bulletin of Kazan National Research Technological University* **16**(10), 80–83

[20] ITS-22-2016 2016 Purification of atmospheric discharge (pollutants) in manufacturing of products (goods), as well as performing works and providing services at large enterprises (Moscow: Byuro NDT) p 198

[21] GOST R 58578-2019 2019 Regulations for establishing environmental standards for odour and performing control of odour emissions (Moscow: Standartinform) p 20