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Aspects of Reducing Odors From Sewage Treatment Plants

Sambursky G.A.[a], Tkachev M.A.[b]
Russian University of Chemical Engineering named after D. I. Mendeleev, 9 Miusskaia Sq., Moscow, 125047, Russian Federation

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Abstract: This article analyzes the literature sources that study the problems of foul-smelling pollutants. The issues of odour rationing from sewage treatment plants are considered. According to the current regulatory legal acts, it is possible to control odorous substances using the olfactory method. An analysis of the factors influencing the formation of foul-smelling substances, as well as methods of their purification, is presented. The advantages and disadvantages of various wastewater treatment technologies have been studied.

1 INTRODUCTION

With the increased pace of technology development, the growth of industrial production and high rates of urbanization, the issue of increased stress on natural resources, in particular on water resources, is on the agenda. Water is the most important resource for the vital activity of living organisms and the environment. The demand for fresh water is constantly growing, as the world's population is constantly increasing, as well as new industries where it is used. As a result of human activity, huge volumes of wastewater are generated, which can be highly polluted or contain toxic substances that pose a danger to the environment and public health. Wastewater with different characteristics, such as volume, concentration, and type of pollutants, is produced in different industries (Kato S., Kansha Y., 2024). Currently, there are several main sources of water pollution: domestic wastewater, agricultural wastewater, industrial wastewater, and surface runoff (Shah, 2017). Pollution can occur by natural inorganic compounds, biological activity of microorganisms, by-products of wastewater treatment processes, as well as spills of various pollutants. Thus, water pollution has a direct and indirect impact on human health (Sharma et al. 2019; Bryukhov, M & Ulrikh, D., 2022).

Since environmental issues are in the focus of attention of all authorities in the Russian Federation, a national project "Environmental well-being" is being implemented from 2025 to solve environmental problems, one of the main objectives of which is to improve the environmental situation in the country. Within the framework of this national project, the federal project "Water of Russia" is being implemented, aimed at improving the health of Russian water bodies and improving the living conditions of the population near water bodies. To achieve these goals, one of the measures implemented within the framework of the project is the construction, reconstruction and modernization of wastewater treatment plants, including minimizing the effects of wastewater treatment plants on the atmosphere and reducing the emission of foul–smelling substances. The main odorous pollutants are hydrogen sulfide (H2S), ammonia (NH3) and volatile organic compounds (VOCs). VOCs are a group of organic compounds such as aldehydes, thioesters, esters, terpenes, benzenes, phenols, pyrazines, and others (Jin Zhu et al., 2025). However, although ammonia is one of the most common foul–smelling substances, due to its high solubility, low hazard and cost-effectiveness, it can also be used for wastewater treatment from hydrogen sulfide and some VOCs, however, it increases ammonia concentrations. In addition to ammonia, organic nitrogen compounds such as quaternary ammonium salt of silicon can also be used as inhibitors and antimicrobial agents to combat sulfides and methane. Nitrogen compounds cause new or interfere with existing biochemical transformations of carbon, sulfur, and nitrogen in

[a] https://orcid.org/0000-0002-6760-2116
[b] https://orcid.org/0009-0002-5650-3726

wastewater through various mechanisms (Yan Chen et al. 2025).In this regard, the issue of developing, searching and implementing the most appropriate wastewater treatment methods in order to minimize wastewater emissions is very urgent at the moment.

2 MATERIALS AND METHODS

The issues of odor rationing from sewage treatment plants have, on the one hand, a high methodological level of support, and, on the other, a mismatch of requirements, since the concepts of comfort and safety are associated with odors, for which different requirements for levels of rationing are established (Figure 1).

When analyzing the current regulatory legal acts regulating emissions from sewage treatment plants, attention should be paid to the following documents (table1).

As can be seen from table 1, the Russian regulatory framework contains documents that help resolve the problem of odor from sewage treatment plants. So in rules 32.13330.2018 "SNiP 2.04.03-085 Sewerage. Pipelines and wastewater treatment plants" introduces an instruction on the method of measuring odor concentrations (olfactory measurements) according to GOST R 58578-2019 "Rules for setting standards and controlling odor emissions into the atmosphere." Olfactory measurement is a method of measuring odor using the human nose as a detector. In this case, concentrations can be determined both by sampling and at the source (field olfacometry) (Orlov et al., 2020). The odor concentration obtained by examining the samples is expressed in odor units per cubic metre (OU/m3). The odor level, which is felt by 50% of the subjects, is considered to be equal to 1 OU/m3 (Yatsenko-Khmelevskaya et al., 2013).

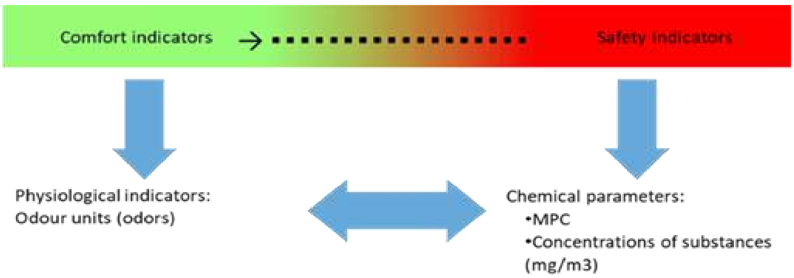

Figure 1: Different emission requirements for foul-smelling substances.

Table 1: Regulatory legal acts regulating the emission of foul-smelling substances:

Regulatory document	Features
Sanitary rules and regulations 1.2.3685-21 "Hygienic standards and requirements for ensuring the safety and (or) harmlessness of environmental factors for humans"	• defines a wide list of harmful chemicals (not just odors!), MPC for populated areas and work areas; • analytical control methods (mg/L) are used; • required for use.
Rules 32.13330.2018 "SNiP 2.04.03-085 Sewerage. Pipelines and wastewater treatment plants"	• describes the requirements for preventing the release of foul-smelling substances and for cleaning them; • required for use.
Handbook of the Best available technologies 10-2019 "Wastewater treatment using centralized wastewater disposal systems in villages and urban districts"	• the best available technology No. 15, the essence of which is a list of recommended technologies and maintaining technological indicators of cleaning criteria (at least 90%); • it is not formally mandatory, but in practice, its observance is a prerequisite for obtaining a comprehensive environmental permit.
GOST R 58578-2019 "Rules for setting standards and controlling odor emissions into the atmosphere."	• describes an organoleptic analysis based on the acuity of the human sense of smell and formed as a statistical processing of the oral responses of the expert commission; • is not mandatory.

3 RESULTS AND DISCUSSION

Unpleasant odor is one of the most acute and common problems. The problem of odor from sewage treatment plants is widespread all over the world. This is due to the fact that with the increased pace of urbanization, structures such as sewage pumping stations, ventilation hoods of channels and sewer collectors, settling tanks, silt maps, etc., which were previously designed and located far from residential areas, now turn out to be built-up country and cottage settlements or may be located within the city (Zaritskaya et al., 2020; Svitskov et al., 2023; Kitikov et al., 2020; Bogdanov A.V., Fedotova A.I., 2023). As noted in (Bogdanov A.V., Fedotova A.I., 2023; Glushchenko E. S., Kadyseva A. A., 2021), according to Handbook of the Best available technologies 10-2019 "Wastewater treatment using centralized wastewater disposal systems in villages and urban districts", wastewater treatment processes can be divided into four groups:

1. processes with the most intensive release: removal of sand on sand traps, compaction of the sediment of the primary settling tank and/or a mixture of sediments, compaction of a mixture of stabilized sediment;
2. processes with intensive release: precipitation of suspended solids in primary settling tanks, biological wastewater treatment on biofilters, compaction of excess activated sludge, mechanical dewatering of sediments, storage of sediment on silt sites and drying sites;
3. processes with significant release: storage of sand on sand sites, biological purification in aerotanks, composting of a dehydrated mixture of sediments from primary and secondary settling tanks;
4. Low emission processes: post-treatment and disinfection of wastewater.

The factors influencing the formation of foul-smelling substances in wastewater transportation systems are (Nartia et al., 2022):

• wastewater composition;

• residence times of effluents in the transport system;

• concentrations of dissolved oxygen in wastewater and collector air oxygen;

• Hydrodynamic features of wastewater transportation and treatment systems;

• routine maintenance (cleaning, flushing, biofouling removal, etc.).

Common approaches to eliminating odors from sewage treatment plants are:

1. Blocking (inhibition) of the processes of formation of foul-smelling substances due to:

• Timely or more frequent cleaning and flushing of collectors and other wastewater transportation facilities;

• Compliance with the high-speed flow regime;

• Preventing the formation of stagnant areas.

2. Organization of effective ventilation of collectors and other facilities for transportation and wastewater treatment, ensuring the required air exchange rates.

3. Zoning of objects to exclude their influence on each other.

4. Localization of foul-smelling substances release points inside the facility in places with maximum concentration.

Based on common approaches, design and technological solutions for odor control are being developed:

• The zoning of wastewater and sludge treatment lines eliminates the possibility of air communication between different facilities (the use of "shutters", etc.).

• Overlap of open storage facilities and channel systems

• Minimizing the air space between the ceiling and the water surface;

• Organization of uniform intake of air from under the ceiling;

• Maintaining a thermal balance, taking into account the multiplicity of air exchange.

For buildings and premises of wastewater treatment plants (mechanical treatment, sludge dewatering, etc.), common approaches to odor control will be:

• ensuring the required frequency of air exchange, taking into account the organization of local suction from the main sources of wastewater (taking into account the creation of a vacuum inside the technological equipment) and ensuring thermal balance;

• ensuring a slight predominance of supply ventilation over exhaust ventilation (10-20%).

It is also necessary to ensure that the influence of free spillage of pressure pipelines in the receiving and distribution chambers and other "waterfalls" is limited.

Since the choice of air purification technologies is inextricably linked to wastewater treatment and transportation technologies (water purification, Figure 2), we propose to formulate requirements for general selection criteria.

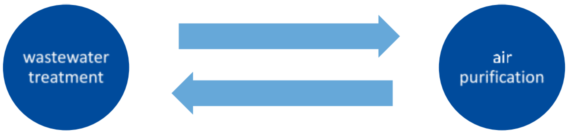

Figure 2: Relationship between wastewater treatment and air purification.

General selection criteria:

1. Technological schemes of wastewater treatment and sludge treatment

2. Requirements for the quality of air purification in work areas, places of release into the atmosphere and at the border of the sanitary protection zone.

3. Climatic conditions (largely determine the choice of technologies).

4. The size of structures, the sequence of construction or reconstruction, and the risks of technological solutions.

Earlier in (Barr et al., 2013), a fairly detailed analysis of technologies for the removal of airborne pollutants by various methods of air purification at Swedish sewage treatment plants and biological waste processing plants was carried out (Table 2).

Since the technologies for cleaning from foul-smelling substances have a finite list, we will consider the main solutions from the perspective of application analysis.

1. Sorption methods for removing foul-smelling substances.

Positive:

• Simple technology;
• practically independent of climatic conditions;
• does not depend on the concentration of foul-smelling substances, if the sorbent is placed correctly.

Cons:

• high operating costs for coal replacement;
• it is really applicable either for low costs and low concentrations of foul-smelling substances, or for a limited period of operation.

2. Chemical sorption methods for removing foul-smelling substances.

Positive:

• classic technology of using acid and alkali scrubbers.

Cons:

• require additional cleaning;
• high operating costs for reagents;
• high consumption of alkali for reaction with carbon dioxide;
• the need for sludge disposal;
• Multiple stages are required for high cleaning efficiency (> 90%).

3. biological methods of removal of foul-smelling substances

Positive:

• Low operating costs.

Cons:

• high capital costs;
• requires significant areas;
• Temperature sensitivity;
• sensitivity to peak concentrations - min and max; the appearance of a secondary odor (after treatment on sorbents is necessary).

Each of the wastewater treatment technologies has its advantages and disadvantages. In this regard, the choice of the optimal cleaning technology depends on the required characteristics and requirements.

Table 2: Comparison of the efficiency of airborne pollutants removal by various methods (according to the Swedish Technical Research Institute).

Method	Number of installations surveyed	Number of surveyed structures	Median1 efficiency, %
Traditional chemical scrubber	13	9	61
Ozone Scrubber	7	5	6
Activated carbon adsorption	19	16	72
Biofilter	26	13	90
Ionization (electric discharge and plasma chemical methods)	8	8	7
Ozonation	10	10	51
Thermal oxidation	6	3	99
Photo-sorption-catalytic method	10	4	98

[1] Half of the surveyed installations have efficiency above the median, and half have lower efficiency.

For example, for the city of Moscow, the characteristics of the air purification system from foul-smelling substances are as follows:

- the climate is temperate continental, with an average January temperature of 6 °C.;
- the range of H2S concentrations at various points in the process chain is from 10 to 200 mg/m3.

Thus, the requirements for foul-smelling substances removal complexes are:

1. The complex must be able to work with dirty air:
   - suspended solids up to 10 mg/m3;
   - aerosols;
   - high humidity, up to 100%;
   - a wide range of inorganic and organic pollutants (hydrogen sulfide, ammonia, mercaptans, VOCs, etc.).
2. Work offline in any climatic conditions.
3. When used in urban areas, the complex should be low-noise.

4 CONCLUSIONS

Environmental safety indicators are currently set in the current laws and regulations. At the same time, multi-year programs for the creation of foul–smelling substances removal systems can be implemented only on the basis of a planned agreed increase in tariffs, with the possibility of tariff differentiation across different territories of the city. We also believe that it is possible to create separate urban odor removal enterprises. It should be borne in mind that better wastewater treatment, the solution of new environmental problems (snow removal, reuse, etc.) and sludge treatment theoretically practically lead to an increase in the release of wastewater at wastewater treatment plants. An increase in the share of domestic wastewater against the background of a general decrease in water consumption leads to an increase in the generation of foul–smelling substances in networks. Therefore, enterprises and regulatory authorities need to realize and accept that eliminating odors is just as important and no less difficult a task than wastewater treatment.:

- it is necessary to create special laboratory, technological and production units integrated into the structure of the enterprise;
- it is necessary to engage in an active struggle for the preservation and expansion of one's own and others' sanitary zones
- fight for reasonable rationing in space and time with the involvement of industry science and public organizations
- convince the authorities that the fight against odors is impossible without a radical modernization of the grid economy.

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