Measures to prevent sewerage odor emissions into the atmosphere

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Abstract. The transportation and treatment of the urban wastewater involves the formation and emission into the environment of fetid substances: sulfur and nitrogen compounds, volatile fatty acids, aldehydes and ketones. Fetidly smelling odors of a sewage system are formed as a result of the anaerobic biological decomposition of organic substances (proteins, carbohydrates), the presence in the wastewater of sulfate-reducing microorganisms that receive energy through the organic substance oxidation. The article considers the methods for determining harmful gaseous substances through chemical and organoleptic analyses, presents a list of the methods used in the Russian Federation and abroad for determining fetidly smelling substances, as well as investigating the advantages and disadvantages of the measures aimed at fighting against fetid odors. Each of the given methods has been implemented using constructional and (or) operational means. It has been stated herein, that the odor neutralization, a correct choice of operational and technical measures, construction technologies, design and hardware solutions (choice of the equipment) require a preliminary surveying of the objects of fetidly smelling substances along the whole pipeline system as part of thorough design and technological studies. The theoretical significance of the research consists in searching for the causes of the gas fetid smells, their intensity control methods and the ways that prevent formation and minimize negative manifestations by construction and operational means. The practical relevance of the performed studies is in a possible application of the got results by the specialists of the sewage system designing and public utility servicing works.

1. Introduction
The process of the urban wastewater treatment is associated with the formation of "wastes", which, first of all, include precipitation and harmful gaseous emissions that have a fetid nature [1, 2]. Almost all elements of a sewerage system can be a source of fetidly smelling odors: treatment facilities, pumping stations, sewerage piping and their constructive structures (wells) [3-5]. Despite the fact, that in general, there is actually no regulatory system with regard to the odors in the atmospheric air in Russia [6], the complaints from the population, as well as prescriptions of the executive authorities, do not allow to ignore the odor control problems either by water disposal servicing specialists or the scientific community. Sewage facility fetid smells often cause resentments of citizens, become a reason for their appeal to supervisory authorities and are a real threat to human health if the maximum permissible concentration is exceeded.
2. Methods
Fetid smells of sewage systems are formed as a result of anaerobic biological decomposition of organic substances (proteins, carbohydrates), the presence in the waste water of sulphate reducing microorganisms, that get the energy through the organic substance oxidation [4]. The work [5] states that odorous compounds, which are emitted by the urban wastewater sewage disposal and treatment facilities, shall be classified into four main groups: reduced sulfur compounds (hydrogen sulfide H2S, mercaptans CH3SH, organic sulfur compounds CH3-S-CH3, CH3-S-S-CH3); nitrogen compounds; volatile fatty acids; aldehydes and ketones.

Herewith, the gases of the first two groups cause the strongest and the most unpleasant odors. According to the work [5], to establish the content of fetidly smelling substances (sulfur and nitrogen) in the air the following methods are used in Europe:

1) a chemical analysis to determine the content of the reduced sulfur compounds using the chromatography method directly at the site of the compound emission, as well as the nitrogen compounds by their adsorption on a solid or liquid medium, followed by desorption and chromatography;
2) an organoleptical analysis based on the smell perception by the human olfaction sense. To perform this analysis, special devices – the olfactometers -have been used (figure 1) [7].

![Figure 1. Mobile olfactometer (a) and laboratory olfactometer (b).](image)

On the territory of the Russian Federation the olfactometry method is used primarily as an independent one. It implies determination of the odor concentration not only directly on the site of the odor source (the field olfactometry), but also by the air sampling into special bags (packages) with further analysis in a laboratory [6].

3. Results
To date, domestic and foreign practical studies have accumulated a big experience in preventing the emission of fetidly smelling odors from sewage facilities into the environment. The odor fighting methods, in the most generalized form, can be classified as follows (figure 2):

1) Blocking (retardation) of the fetidly smelling substance formation in the liquid phase;
2) Reducing the spreading of fetidly smelling substance emissions in the gas phase.
Retardation of the fetidly smelling substance formation in the liquid phase can be provided by operational and (or) construction measures. The operation and servicing measures include:

1) Flushing of pipelines. It helps to eliminate plaque and alluvial silt (sediments) from the pipe walls and, as a result, to prevent the fetid smell formation. An effective flushing of pipelines can be carried out by water-air, hydrodynamic, hydraulic, pulse, hydro-chemical or hydro-barodynamic methods [2].

2) Dosing of reagents. The process consists of adding the nitrates or Fe (III) oxide to the wastewater stream. The nitrates prevent the creation of anaerobic conditions and, consequently, odorous compounds. The ferric oxide, reacting with hydrogen sulfide, forms a slightly soluble iron sulfide, preventing the release of hydrogen sulfide into the environment [8].

3) Ventilation. A forced or natural air exchange can be used in compliance with the requirements of clauses 6.9.1-6.9.5 [9].

4) Regulation of the pumping station operations. The process consists in a more frequent pump switching on, which shall result in a shorter waste water residence time in the receiving chamber.

The main constructional measures consist in:

1) Reconstruction of pipelines. In the pipeline sections, which are characterized by wastewater flow rates lower than those recommended in the clause 5.4.1 [9], possible greater pipeline slopes should be considered. In the pipeline areas with increased rates of the pipe filling (more than 0.8), it may be recommended to replace the existing pipes with those ones of a larger diameter. These measures, respectively, enable to increase the speed of flow rates, which prevent silting, as well as exclude the oxygen-free regime in the pipeline. In recent years, a particular relevance has been attributed to the pipeline trenchless reconstruction technologies that provide optimal hydraulic modes of waste water flows [2, 10, 11].

2) Changing the design of drop wells. According to the clause 6.4.1 [9], it is allowed to perform drops of up to 0.5 m in the well without provision of a pipe riser. At the same time, according to scientific studies [12], in order to prevent the emission of fetidly smelling odors into the atmosphere through the drop wells, the mode of the waste water flows should be taken into account. For example, in the case of an aerobic regime supported by an effective ventilation of the gas medium within the pipeline subsurface space (with fillings less than 0.7), provision of open drops prevents the odor formation.
formation due to additional saturation of waste water with oxygen, and, as a result, eliminates the processes of rotting of organic compounds. But if the sewage water flows in a pipeline under the anaerobic regime (when filling is close to 1.0), provision of drop wells with open spillways causes the emission of unpleasant odors into the atmosphere. These information data should be taken into account at the design stage of newly constructed or reconstructed sewage pipelines.

Removal of fetidly smelling substances from the gas phase, as well as from the liquid phase, can be achieved by operational measures. One of the promising methods is the use of deodorizing compounds (aerosols) sprayed in the zone of permanent smell formation (silt areas, sludge mechanical treatment facilities, pumping stations).

The construction measures to remove fetidly smelling substances from the gas phase consist in the design improvement of sewage water disposal and treatment facilities:

- overlapping of the waste water open surfaces at the territory of treatment facilities (supply channels, receiving chambers, settling tanks);
- equipping the inspection wells, which emit unpleasant odors, with filters. The function of a filter (built under the manhole of the well or installed above its neck outside of improved coverings) consists in biological or sorption purification of the gas phase from fetidly smelling substances. The literary sources [3, 13] describe a positive experience of operation of such structural constructions.

Treatment of fetidly smelling substances in the gas phase can be carried out by:

1) Thermal methods. They consist in high-temperature hydrogen sulfide combustion in the furnace part of the reactor-generator when a stoichiometric amount of air is supplied (the Claus method) [14]. The method is implemented at a temperature of 1100-1300°C according to the following chemical reaction:

\[ 2\text{H}_2\text{S} + \text{O}_2 = \text{S}_2 + 2\text{H}_2\text{O} \]

2) Biological methods. They are based on the fetidly smelling substance sorption in organic or inorganic media with colonized microorganisms (fungi, bacteria) [1]. This method of gas purification is carried out in biofilters or bioscrubbers. The shortcomings of such structures consist in the need to place them in positive ambient air temperature conditions, as well as a low permissible limit of the hydrogen sulfide initial concentration to be emitted from the mixture of the gas stream under treatment.

3) Physical and chemical methods. These methods are implemented through absorption or adsorption processes [14]. The following absorption methods are used:

- chemical absorption (consists in the chemical interaction of hydrogen sulfide with the active part of the absorbent, such as alkanolamines, alkali solutions, solutions of alkali metal salts and solutions of iron hydroxide). The chemical absorption makes it possible to achieve a high degree of the gas purification from the hydrogen sulfide H₂S;
- physical absorption (based on the solubility of various gas components in the absorbent; in addition to hydrogen sulfide, the method allows the extraction of mercaptans). Regeneration of physical absorbents is less economically expensive than regeneration of chemical absorbents;
- physical and chemical absorption (combination of chemical and physical absorbents).

The gas purification adsorption methods are based on the separation of gas components by solid absorbers (adsorbents). In practice, the following adsorption methods are used:

- chemical adsorption (the released gas components enter into chemical interaction with the adsorbent). There is a positive experience of using cold methanol, poly - and ethylene carbonate to extract CO₂ and H₂S [15]. However, the method is not widely used because of the complexity of the adsorbent regeneration;
- physical adsorption (the released gas components are held by the adsorbent by physical interaction forces, mainly van der Waals forces); the technology is characterized by an easy regeneration of the adsorbent, as well as high rates of the gas purification from hydrogen sulfide and carbon dioxide. The activated carbons and synthetic zeolites are most commonly used as adsorbents. Desorption (the adsorbent regeneration) is carried out by heating, vacuuming or purging with an inert gas. At the same time, any of the above regeneration methods requires significant energy power [16].
The main advantage of the adsorption cleaning methods over the absorption ones is the higher absorbing capacity of the adsorbents.

4) Catalytic methods. They consist in a fine gas purification from sulfur compounds using various catalysts (cobalt-molybdenum, Nickel-molybdenum, disulfide-molybdenum, etc.). The widespread use of the method is constrained by complicated issues of the catalyst regeneration process, as well as the need to pre-treat the gas from mechanical impurities that significantly reduce the activity of the catalysts [17].

5) Membrane methods. They are based on the removal of acidic gas components (methane, carbon dioxide, hydrogen sulfide) using membrane materials such as silicone rubber, cellulose acetate (triacetate) [18]. The membranes used for the gas treatment are made in the form of flat sheets or hollow fibers, so the modifications of the modules can be represented by rolled (figure 3) or hollow-fiber (figure 4) modules. To date, the use of membranes for the gas treatment makes about 5% of the global productivity of the gas treatment plants [19]. From the economic point of view, the use of membranes is mostly justified at middling volumes of the gas to be treated.

6) Electro-physical methods. The methods consist in the gas molecule ionization by electric shocks, as a result of which they are split into positively charged ions and electrons that can move in the direction of the lines of force [20].

4. Discussion

Among all complaints of the population related to dissatisfaction with the environment, the complaints about unpleasant smells make up about 50%. The problem of fighting unpleasant odors is relevant both in terms of transportation and treatment of the urban wastewater. The total solution of the smell problem is possible, if provision is made of comprehensive measures to be taken to eliminate (minimize) fetidly smelling emissions into the environment. In this case, it is necessary to be guided by the fact that the smell must be blocked in the liquid phase or reduced to the maximum permissible concentrations in the gas phase. The expediency of each above given method shall be determined by all peculiar properties and characteristics of the wastewater disposal and treatment system. As a rule, one single method does not enable the desired result.

5. Conclusions

1. The review and analysis of the methods presented in this work aimed at preventing emissions of fetidly smelling gases from sewage facilities have both theoretical and practical significance.

2. The theoretical significance of the presented materials is the systematization of the global experience of fighting unpleasant odors, which means possible identification of the most optimal methods for eliminating harmful gaseous substances.
3. The practical significance of the work consists in the possible use of the presented methodic materials for removal of fetidly smelling substances by specialists, who serve the public facilities and utilities, by timely performance of operation works on diagnostics and cleaning of the pipelines. The got materials shall be useful for sewer system designers, who can be guided by means of ensuring optimal hydraulic performances of the pipes without any or effectively reduced negative consequences of the existing harmful gaseous substances.

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