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Environmental Safety of the Sewage Disposal by the Sewerage Pipelines

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Abstract

The concentration of hydrogen sulfide and other gases in the sewerage pipelines of the Kharkov city was measured during the experimental studies. Based on the obtained figures the emission of hydrogen sulphide through the sewer shafts in urban environment and its dispersion in the atmosphere of specific urban areas were estimated. The interface of the page for the monitored indicators of the environmental safety and operational reliability of specific areas of the water disposal pipelines was developed. It can be used for the geographic information system of the urban sewer networks.

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Keywords: sewerage pipelines; gaseous emissions; hydrogen sulfide; environmental safety; data visualization; geographic information systems.

1. Introduction

The sewage disposal by the sewerage pipelines brings a range of risks for environmental safety of air, water and soil environments in settlements. Thus formation and emission of gas compounds from the sewer nets through the sewer shafts and manholes pollute the atmosphere in neighboring urban districts, as in these emissions concentration of series of the compounds mainly sulfur-containing – hydrogen sulfide, sulfur dioxide, mercaptan (alkyl sulphydrate), dimethyl sulphide (DMS), exceeds not only daily average MPC for residential areas, but also MPC for working ones. The highest rate of MPC excess in gas release from the sewer nets is marked for hydrogen sulfide – highly toxic and

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chemically active compound of the second hazard category (MPC working area – 10, MPC daily average – 0.008 mg/m³). Besides, the concentration of hydrogen sulfide, its derivatives and oxidation products in operational environments of the concrete sewerage pipelines (fine water, underroof space, condensate water on the roof) activate biogenic sulfuric corrosion of the roof, that reduces operating life of these pipelines (from planned 50 to 10–15 years). The biogenic corrosion causes 70–75% of reinforced sewerage pipelines breaks, which are followed by failures and landslip seams in the grounds of residential construction and transport systems, destruction of municipal services, pollution of soil and water environments. Frequency of reinforced sewerage pipelines breaks (whose length is 25% of length of the whole sewer net) is 1.8–4.6 km/year, i.e. 2–4 times higher than at the ceramic ones and 20–40 times higher than at the brick ones (Дрозд 2003; Stein 2001; Stuetz 2001; Zhang 2008; Васильев 2013; Юрченко 2014).

Permanent control (monitoring) of this compound concentration on the sections of the net, information storage and rendering to the maintenance departments of the sewer nets in the modern form are necessary for provision of ecological safety and operation reliability of the sewage disposal by the concrete pipelines (development and implementation of gas emission cleaning methods, squelching methods of processes, producing hydrogen sulfide).

2. Ecological consequences of the hydrogen sulfide concentration in the sewerage pipelines

The gravity sewerage pipeline can be considered as a technogenic ecosystem, which includes three phases: liquid (sewage disposal), gas (air of the main drainage channel) and solid (concrete of the roof) and their microbiocenosis. Such pipeline is a specific "reactor", where spontaneous chemical and microbiological processes are proceeded. They cause formation of the gas compounds in sewage disposal, which are evolved in the air of the underroof space of the gravity pipelines, are partially dissolved in condensate water on the roof of the buildings and interact with concrete either directly or after microbiological transformations (Table 1) (Юрченко 2014).

Formation of hydrogen sulfide in the sewage disposal results from microbiological processes of disassimilation sulfate reduction (renovation of sulfates with the hydrogen sulfide emission), which obligate aerobic sulfate-reducing bacteria perform.

Table 1. Chemical compounds in air of the underroof space of the sewerage pipelines (Юрченко *et al.* 2014).

Compounds	Concentration in emissions	Rate of MPC excess$_{working\ area}$
CO_2, volume %	0.1–3.5	To 7
CO, mg/m^3	0–25	To 1.4
CH_4, volume %	0.2–6.0	To 3
H_2S, mg/m^3	0–250	To 25
SO_2, mg/m^3	5–30	To 3
Dimethyl sulphid, mg/m^3	(1–4) 10^{-4}	To 10^2
NH_3, mg/m^3	0–5.0	To 4
NO_x, mg/m^3	0–5.0	–

The activity level of hydrogen sulfide formation and its emissions in the air of the pipeline depends on many factors: COD of sewage water, concentration ratio of sulfates and COD, temperature, pH and Eh of sewage water, flow turbulence and others. (Дрозд 2003; Юрченко 2014). Thus the hydrogen sulfide concentration in the underroof space of different sections fluctuates very significantly even within 24 hours (Бригада 2013). Regulation of the hydrogen sulfide concentration in the underroof space air of the sewer nets, carried out at regular times as a rule, does not allow to estimate reasonably the condition. The processes of hydrogen sulfide emission through the sewer shafts into the urban environment and its dispersion are studied rather partially. The particular calculations and measurements testify high ecological hazard of the process for the urban environment.

The methods of operating monitoring of theses objects corrosion damage and concentration activity of hydrogen sulfide in them are necessary for reliability control of concrete sewerage pipelines running and increasing of their operating life.

3. Objects and research methods

The object of this research was an experimental evaluation of gas emissions hazard from the sewerage pipelines of Kharkiv for environment, development of a visual monitoring system of indices of ecological safety and operating reliability for these objects.

The experimental researches were carried out on the sections of the sewer nets of Kharkiv. The measurements of the hydrogen sulfide concentration in the environment of the underroof space were performed with three gas analyzers: UG-2, "Dozor", a shaft interferometer ShI-11. The average annual concentration of hydrate sulfide in the gaseous fluid at the different height of the sewer shafts was established by the method, developed in (Бригада 2013). It is based on the nondestructive evaluation of the depth of biogeneous corrosion concrete with a concrete corrosimeter – a device, authorized in Ukraine.

The obtained data was applied for the calculation of the hydrogen sulfide concentration in the gaseous emission and for calculation of its dispersion in the environment of the particular districts in Kharkov. The calculation of hydrogen sulfide dispersion was performed with the program "EOL +". OND-86 (National statutory document) "Calculation procedure of repugnant substances concentration in open air, contained in emissions of enterprises" is basically applied to the calculation.

The visualization of the monitoring system of the ecological safety and operating reliability of the sewerage pipelines in Kharkiv was carried out with the help of the specialized software, based on the ecological charting procedure and the geoinformational technologies.

4. Results and discussion

The chemical composition of the underroof space environment of the sewerage pipelines, identified in different sewer shafts in Kharkiv, is presented in Table 2, Fig. 1.

Table 2. The gas substance concentration in the environment of the sewer nets in Kharkiv.

No of shaft	Concentration				
	SO_2, mg/m^3	H_2S, mg/m^3	CO, mg/m^3	CO_2, volume %	CH_4, volume %
1	18	40.1	2.6	0.73	1.1
2	8.6	20.4	2.1	0.73	1.1

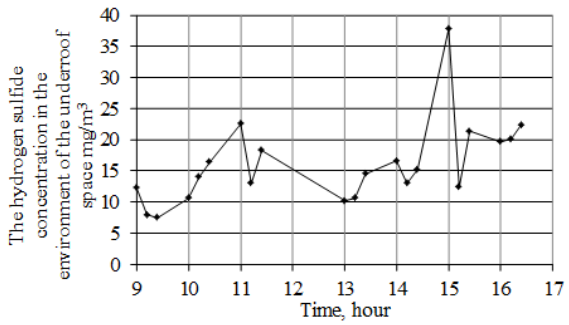

Fig. 1. Dynamics of the hydrogen sulfide content in the environment of the underroof space of the sewerage pipelines.

As it is seen from the represented data, the hydrogen sulfide concentration exceeds 2–4 times MPC for working area at two studied sections. Within 24 hours the hydrogen sulfide concentration in the environment of the underroof space of one of the sections fluctuates in a rather wide range (6–38 mg/m^3).

Sewerage pipeline laying depth in Kharkiv is 40 meters at some sections. Gas hydrogen sulfide is heavier than air and thus its concentration at the output from the shaft is less than the concentration, determined under the surveying of the

pipelines. Degradation of the concentration depends on aerodynamic environment, that determines draft at the given section, temperature inside the shaft and ambient temperature, height of the shaft and others.

These factors are required to be averaged for longer period taking into account the sizable fluctuations of the hydrogen sulfide concentration in the environment of the underroof space, the broad range of aerodynamic environment changes and temperatures. The measurement of corrosion rate of the concrete heightwise of some sewer shafts at different sections of sewage environment were applied for such averaging. With the help of the obtained data the averaging dependence, represented in Fig. 2, was formed. As it is seen from the represented data, degradation of the hydrogen sulfide concentration is approximately 7.4% for every meter of the shaft height.

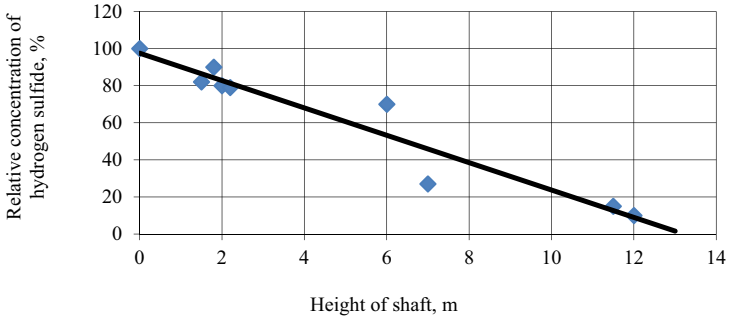

Fig. 2. Dependence of degradation of relative hydrogen sulfide concentration in the air-gas environment on the shaft depth.

The calculation of gas emissions dispersion in the districts, where the sewer shafts No 1 and No 2 are located, was performed. Daily average MPC (0.008 mg/m^3) was taken as a standard indicator. The depth of the surveyed shafts was 12 and 10 m. The height of the emission sources above ground was taken equal to 0.05 m. The baseline data for the calculation of dispersion is represented in Table 3, the data of the dispersion is represented in Table 4. The dispersal map of hydrogen sulfide, released from the shaft No 1 into the atmosphere of the particular urban district, is represented in Fig. 3.

Table 3. Parameters of the emission sources of polluting substances into the urban atmosphere from the sewer shafts.

Emission source	Parameters of the emission source		Characteristic of the gas-air mixture at the output		Concentration H_2S, mg/m^3		Emission rate, g/s
	height, m	diameter, m	velocity, m/s	temperature, °C	in the pipeline	at the output from the mine	
Shaft No 1	0.05	0.7	1	18	40.1	4.01	0.004
Shaft No 2	0.05	0.7	1	18	20.4	5.1	0.005

Table 4. Calculation data of hydrogen sulfide dispersion.

Emission source	Distance to the residential construction, m	Concentration of H_2S in the residential area, MPC part	Distance to the safe area, m
Mine No 1	35	3,19	225
Mine No 2	30	4,58	260

As it is seen from the represented data, the residential construction on the surveyed section is located in the environmentally fragile area: the hydrogen sulfide concentration in the open air exceeds MPC.

For protection of the urban environment from the gas compounds pollution, released from the sewerage pipelines, the degasifier traps, which provided high results in hydrogen sulfide removal, were erected by the managing company.

Appliance of these degasifiers at other sections of the sewer net has to be based on the monitoring data of hydrogen sulfide emission from the sewer shafts.

Fig. 3. Calculated dispersion of hydrogen sulfide, released from the water disposal pipeline in the section of the sewer shaft (in Ukrainian).

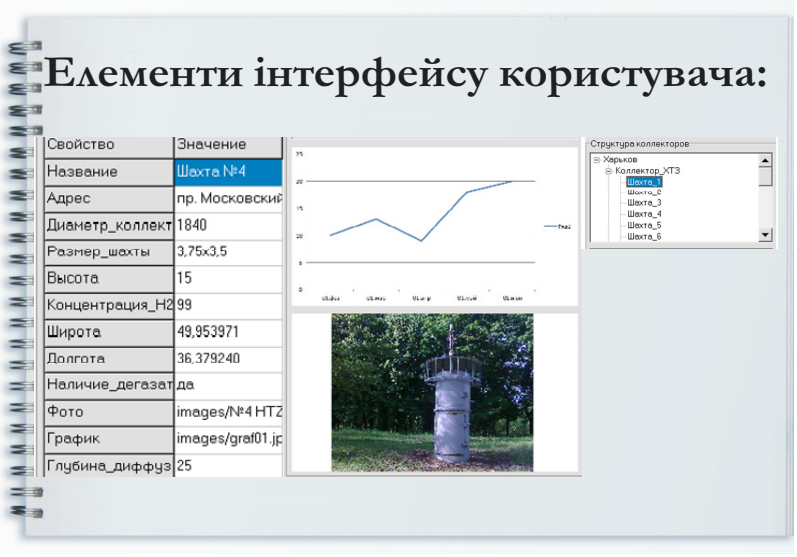

Fig. 4. The interface of the page with the monitoring parameters of operating reliability of the separate sections of sewer (in Ukrainian).

Gathering of objective information on quantitative characteristics of formation and emission of hydrogen sulfide, depth and velocity of biogeneous corrosion of concrete at different sewer shafts of the net in Kharkov, allowed to form a data base, that is necessary for creation of the page, that is compatible with the geoinformational system of the sewer nets, existing at the enterprise. The developed methodology of visualization of the ecological safety and operating reliability parameters at the separate sections of the sewerage pipelines includes recording of the hydrogen sulfide concentration in the sewage disposal and the hydrogen sulfide concentration in the air-gas environment, recording of calculating velocity of concrete corrosion, rate of MPC excess as per hydrogen sulfide in gas release, availability of protection tools of atmosphere (degasifiers) and others.

For visualization of ecological and operational parameters the interface of the page is designed with the ecological safety and operating reliability parameters of the separate sections of the sewerage pipelines for the geoinformational system of the urban sewer nets (Fig. 4).

5. Conclusions

1. The performed measurements show that the hydrogen sulfide concentration in the atmosphere of the underroof space of the sewerage pipelines within 24 hours changes in a wide range.
2. Kinetics of degradation of the hydrogen sulfide concentration, that is released from the sewerage pipeline heightwise of some sewer shafts, is determined
3. The performed calculations of hydrogen sulfide dispersion, released from the sewerage pipelines, show, that at some sections of the sewer net the environmentally safe area is at a distance of 225–260 m from the shafts.
4. The interface of the page is designed with the monitoring parameters of the ecological safety and operating reliability at separate sections of the sewerage pipelines for the geoinformational system of the urban sewer nets.

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