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Assessment of the Current State of Atmospheric Air Pollution of the Gas Processing Plant in the Territory of the Transboundary Arctic Region

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ABSTRACT

Extraction of natural resources in the Arctic region is difficult and dangerous from an ecological point of view. Under the conditions of the harsh Arctic climate, the probability of emergency situations increases significantly. The transboundary part of the Arctic region is also characterized by difficult climatic conditions. Strong environmental pollution is caused by the development of oil and gas production, as well as processing of oil and gas products at industrial plants. All this calls for a change in the basic elements of the environment: soil, air, water, etc. It is accepted that air can be considered as the initial link in the chain of environmental pollution and objects. Therefore, it is important to monitor the impact of emissions from the oil and gas industry into the atmosphere. Hence, there is a need to assess the condition of the air basin. The purpose of the study: to assess the degree of atmospheric air pollution as a result of the operation of a gas processing plant for various pollutants. In the course of the work, based on the analysis of the proposed criteria for assessing the existing state of the atmosphere and atmospheric air pollution, the degree of atmospheric air pollution by various pollutants was assessed. The characteristics and parameters of emissions were obtained, the polluting element with the highest emission value (methanol) was installed, and the boundary of the sanitary protection zone was constructed. On the basis of the results of the work carried out, it was concluded that the air basin of the area under consideration is characterized by: severe climatic conditions, low self-cleaning ability of the air basin, limited favorable ability to decompose pollutants entering it, favorable ability to wash out harmful substances, and relatively favorable hygienic condition of the air basin.

Keywords: air pollution, methanol, sanitary protection border, gas processing plant.

INTRODUCTION

The environment in the Arctic as a special area of international cooperation is an integral and topical issue of any projects in the region. Environmental safety should come first. For Russia, which has the longest Arctic coast in the world, environmental protection in the Arctic is a matter of strategic necessity. A healthy ecosystem, stable availability of natural resources, preservation of unique flora and fauna, prevention of emergency situations on the Northern Sea Route, in the areas of natural resources development on the Russian continental shelf are extremely important tasks, the solution of which depends on the coordinated work of the regional authorities of the Russian North and federal state authorities. In addition, in addition to the Arctic zone itself, the cross-border territories t hat are subject to active industrial development, play an important role. Therefore, such territories also affect the environment of the Arctic zone on its boundary parts [Ivanov, 2013].

The oil is one of the most important types of energy raw materials. In the near future, the energy needs of industrialized countries will continue to be met mainly by oil. The oil production on the continental shelves will develop especially rapidly. The oil refineries emit a huge amount of harmful substances. The production of fuel materials is accompanied by the release of compounds of heavy metals, sulfur, nitrogen, carbon dioxide, chlorine, and dioxins. They cause diseases of the respiratory system in humans. Every year, oil-producing enterprises carry out a large complex

of environmental measures. However, only the main and priority activities have been carried out in this area. Therefore, there is the problem of nature conservation and rational use of natural resources. The negative impact of oil production and refining processes on the environment is enormous. In order to preserve the normal biosphere of the planet, it is necessary to pay more attention to environmental issues, as well as introduce and finance safe technologies and methods of protecting nature from the consequences of oil extraction and refining [Khairullina & Makhmudova, 2019].

The oil and gas industry is one of the most environmentally hazardous economic sectors. It is characterized by a large ground capacity, significant polluting capacity, in addition to high explosive and fire hazard of industrial facilities. The chemical reagents used in drilling wells, oil production and preparation, as well as extracted hydrocarbons and impurities to them are harmful substances for flora and fauna, as well as for humans. The oil and gas production is dangerous due to the increased accident rate of work, because the main production processes occur under high pressure. Field equipment and pipeline systems operate in aggressive environments. There are two extreme opposing opinions on environmental issues. The first is connected to the fact that intervention in the environment must be sharply limited, because modern management methods can lead to catastrophic consequences [Kolokoltsev, Ostrovskaya, & Kolmykov, 2015; Skripkina, 2016; Hashirova, Akbasheva, Ushakova, & Akbasheva, 2017; Sakharova, Arapova., Alekseychik, & Bogacheva, 2018]. The other opinion is that the potential for self-restoration of nature is quite large, and therefore it is not necessary to spend large amounts of money on its protection and reclamation work [Fedorov, Kulikov, & Fedorova, 2012].

The atmosphere is one of the elements of the environment that is constantly exposed to human activity. The consequences of this impact depend on various factors and are manifested in changes in climate and the chemical composition of the atmosphere. These changes significantly affect the biotic components of the environment, including humans. It is accepted that air can be considered as the initial link in the chain of environmental pollution and objects. Often, soils and surface waters are indirect indicators of its pollution, and in some cases, on the contrary, they can be sources of secondary pollution of the air basin. Hence, there is a need not only to assess air pollution, but also to monitor the possible consequences of the interaction of the atmosphere and adjacent environments, as well as to obtain an integral (mixed) assessment of the state of the air basin.

The purpose of the study was to assess the degree of atmospheric air pollution as a result of the operation of an oil-producing enterprise. In this regard, important tasks are to study the process of environmental pollution, to determine changes in the level of anthropogenic load, and to assess the possible effects of emissions of harmful substances from gas processing plant facilities on the existing state of environmental elements. On the basis of the available data, an assessment of the existing and projected state of the environment (atmospheric air) was carried out using devices for collecting concentrations of air pollutants.

MATERIAL AND METHODS

Research area

The study was conducted at a gas processing plant located on the territory of the Khanty-Mansiysk Autonomous Okrug – YUGRA, which can be classified as a cross-border Arctic region of Russia. The Khanty-Mansiysk Autonomous Okrug – Yugra (KhMAO-Yugra) acts as the object of research: its geographical location has led to a unique natural resource potential, and the territory itself is characterized by a certain natural, economic and socio-cultural unity. Natural and climatic conditions close to the Arctic and a high standard of living, result in active migration flows that affect the cultural landscape of the territory.

The plant, established in 1978, is located near the settlement (the city of Pyt-Yakh) (Figure 1). The capacity of the plant for receiving associated petroleum gas for processing is more than 3 billion cubic meters per year, which allows annually preventing emissions into the atmosphere of about 10 million tons of greenhouse gases in CO_2 equivalent. The plant produces dry distilled gas, which is the main raw material for petrochemical enterprises.

The ecological situation in the area under consideration is caused by many factors, the most important of which are: low biological activity and scarcity of local flora and fauna, climatic features due to a long period of negative temperatures, as

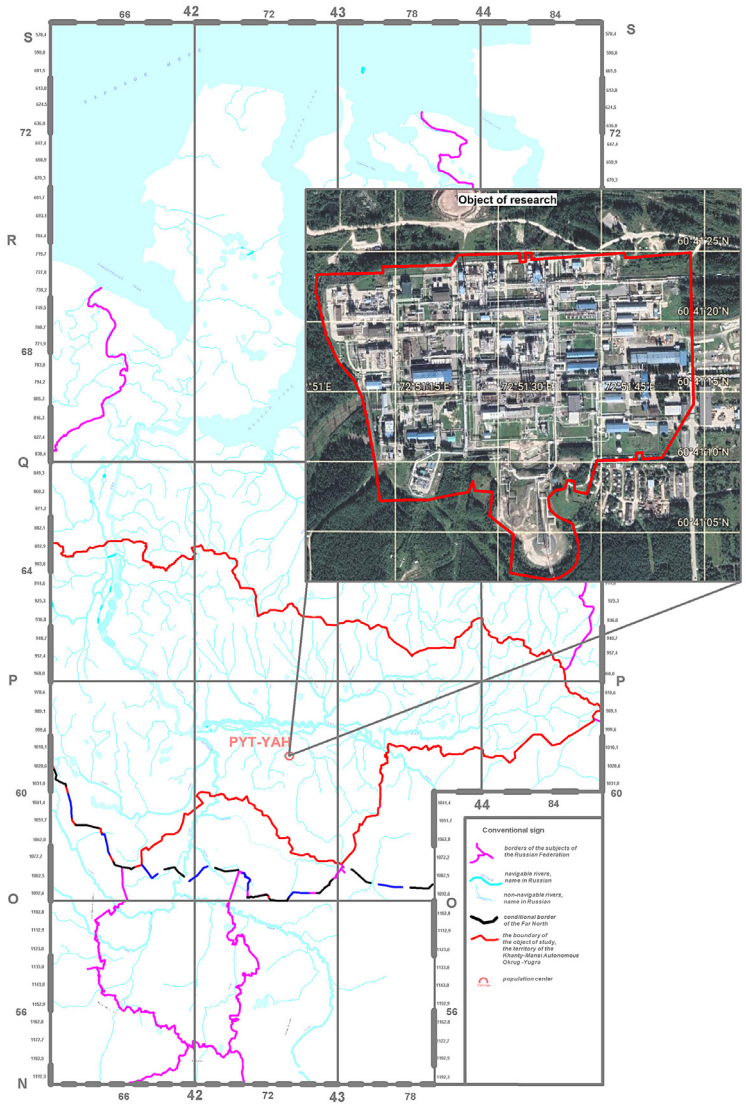


Fig. 1. Geographical location of the research area

well as man-made impacts. The study included using specialized instruments to collect the data on concentrations of air pollutants of the gas processing plant. The concentrations of 34 substances were measured.

Meteorological potential of the object of study

The current state of the air basin of the area where the gas processing plant is located is determined mainly by climatic conditions (since they affect the ability of the atmosphere to self-purify) and the level of existing anthropogenic pollution of the air basin. One of the important climatic characteristics of the territory under consideration is the meteorological potential. The meteorological potential lies in the regional and local features of the atmosphere for the accumulation or dispersion of emissions of harmful substances. The meteorological potential is determined by meteorological characteristics: the frequency of recurrence of calm and low wind speeds, the frequency of recurrence of inversions and other characteristics.

For the territory under consideration, the percentage of recurrence of inversions ranges from 40 to 60% with their power in winter from 0.6 to 0.8 km, and in summer – no more than 0.4 km. The repeatability of wind speeds from 0 to 5 m/s is from 10 to 30% (in all seasons of the year). The wind rose is shown in Figure 2.

Thus, the area under consideration is characterized by a moderate potential for pollution of the air basin, in connection with which equally probable conditions are created both for the dispersion of pollutants emitted into the atmosphere and for their accumulation.

Month	N	NW	W	WS	S	SE	E	NE	Calm
January	3	7	13	10	13	26	22	6	13
July	22	13	15	8	7	10	13	12	10
Year	11	8	12	9	10	18	21	11	10

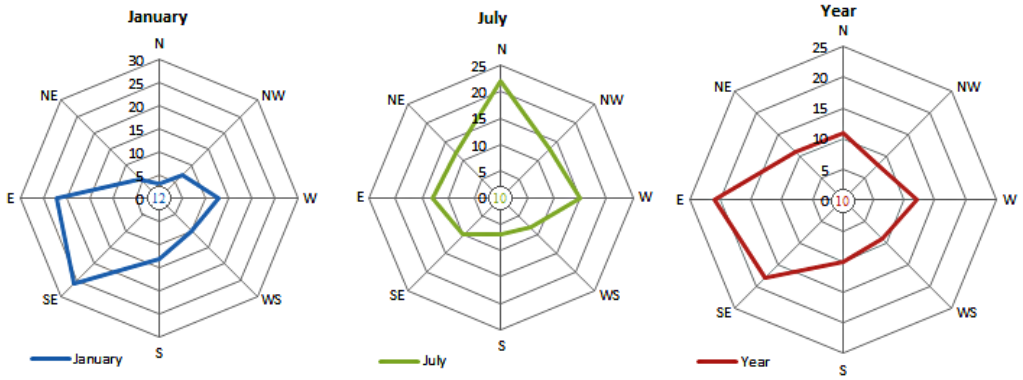


Fig. 2. Repeatability of wind directions and the number of days with calm (the number in the circle)

ASSESSMENT OF THE EXISTING STATE OF THE ATMOSPHERE AND ATMOSPHERIC AIR POLLUTION

To assess the level of atmospheric air pollution, characteristics and ecosystem indicators of changes in the level of air pollution, indicators of atmospheric air quality, ecosystem indicators and risk are usually used. The air environment can be assessed in two aspects:

1. Climate and its changes under the influence of natural causes and anthropogenic influences in general (macroclimate) and this project in particular (microclimate). These estimates assume a forecast of the potential impact of climate change on the implementation of the projected type of anthropogenic activity.
2. Atmospheric pollution. To begin with, the possibility of atmospheric pollution is assessed using one of the complex indicators, such as: the potential of atmospheric pollution, the scattering capacity of the atmosphere, and others. After that, the assessment of the existing level of atmospheric air pollution in the required region is carried out.

The conclusions about climatic and meteorological characteristics as well as about the source of pollution are drawn, first of all, on the basis of the data from the regional branch of the Federal Service for Hydrometeorology and Environmental Monitoring, then on the basis of data from the sanitary and epidemiological service and special analytical inspections of the State Committee of Ecology, also based on various literary sources.

As a result, based on the estimates obtained and the data on specific emissions into the atmosphere of the projected object, calculations of the forecast of air pollution are carried out, while using special computer programs that allow not only assessing the possible levels of air pollution, but also obtaining a cartographic diagram of concentration fields and data on the deposition of pollutants on the underlying surface.

The criterion for assessing the degree of atmospheric air pollution includes the maximum permissible concentrations (MPC) of pollutants. The measured and calculated concentrations of pollutants in the atmosphere can be compared with the MPC and, therefore, atmospheric pollution is measured in MPC values. At the same time, it is worth paying attention to the fact that the concentrations of pollutants in the air should not be confused with their emissions. Concentration is the mass of a substance in a unit of volume (or mass), whereas emission is the weight of a substance received in a unit of time ("dose"). The emission cannot be a criterion of air pollution; however, since atmospheric pollution depends not only on the mass of emissions, but also on other factors (meteorological parameters, height of the emission source, etc.).

The air pollution forecasts are used within the framework of construction to predict the impact of factors from the impact of a polluted environment. When carrying out an environmental assessment, the assessment of the state of the air basin is based on a comprehensive assessment of atmospheric air pollution in the study area, while using a system of direct, indirect and indicator criteria. The

assessment of air quality (first of all, the degree of pollution) is quite well-developed and is based on a huge number of legislative and policy documents that use direct control methods to measure environmental parameters, as well as indirect calculation methods and evaluation criteria.

Direct evaluation criteria. The main criteria for the state of atmospheric air pollution include the values of maximum permissible concentrations (MPC). It should be noted that the atmosphere is also a medium for the transport of technogenic pollutants, and constitutes the most variable and dynamic of all its abiotic components as well.

The most important indicators reflecting atmospheric pollution are the maximum permissible concentrations (MPC) [Maximum permissible concentrations (MPC) of pollutants in the atmospheric air of populated areas: Hygienic standards. GN 2.1.6.1338-03, 2003]. MPC is the maximum permissible concentration of a pollutant in the atmospheric air, which does not have a direct or indirect adverse effect on the present or future generations throughout life, does not reduce a person's working capacity, and does not worsen his well-being and sanitary living conditions. MPC is measured in mg/m^3. MPC can be of various time-differentiated indicators: maximum one-time MPCmr (short-term effects), average daily MPCss and average annual RDCg (for longer-term effects).

Currently, the maximum permissible concentrations in the atmospheric air of more than 500 substances have been determined. It is worth noting that MPC is the maximum concentration of an impurity in the atmospheric air, attributed to a certain averaging time, which, with periodic exposure or throughout a person's life, does not and will not have a harmful effect on him (including long-term consequences) and on the environment as a whole.

The degree of air pollution can be assessed by repetition and frequency of exceeding the MPC, taking into account the hazard class, as well as by summing up the biological effects of pollution. There is a division of pollutants in the air according to the probability of their adverse effects on human health, which includes 4 classes:
1) first class – extremely dangerous.
2) second class – highly dangerous;
3) third class – moderately dangerous;
4) the fourth class – not very dangerous.

Basically, the actual maximum one-time, average daily and average annual MPC are used in comparison with the actual concentrations of pollutants in the air over the past few years, but not less than 2 years.

The most common and informative indicator of atmospheric pollution is the indicator of the complex index of average annual atmospheric pollution. The distribution of atmospheric conditions by classes occurs in accordance with the classification of pollution levels on a four-point scale:

- class "norms" – means that the level of air pollution is below the average in the cities of the country;
- "risk" class – equal to the average level;
- "crisis" class – above average;
- the "disaster" class is much higher than the average level.

Basically, the complex index of average annual atmospheric pollution is used for comparative analysis of air pollution in different parts of the studied territory (cities, districts, etc.), as well as to assess the time trend regarding the state of air pollution.

In addition, the use of cartographic methods of air assessment allows establishing the boundaries of the sanitary protection zone of the enterprise. In order to protect the atmospheric air in the places of residence of the population, sanitary protection zones of organizations are established. The sizes of such sanitary protection zones are determined on the basis of calculations of dispersion of emissions of harmful (polluting) substances in the atmospheric air and in accordance with the sanitary classification of organizations [SanPiN 2.2.1/2.1.1.1200-2003 Sanitary protection zones and sanitary classification of enterprises, structures and other objects]. The current state of the atmosphere and atmospheric air pollution were assessed according to the following criteria:

- The ability to decompose pollutants in the atmosphere;
- Ability to wash out harmful substances from the atmosphere;
- The ability to decompose the pollutants entering the atmosphere of the area under consideration was determined by the amount of ultraviolet radiation;
- Self-cleaning ability of the territory according to the degree of dilution of pollutants.

The area under consideration is located in high geographical latitudes – Khanty-Mansi Autonomous Okrug, Tyumen Region. This causes a

low influx of solar radiation and the formation of a cold climate. In general, the climatic conditions in the area under consideration are severe with somewhat limited radiation resources, a shortage of ultraviolet radiation and insufficient insolation resources. These climatic characteristics allow assessing the ability of the air basin of the area under consideration to decompose the impurities of anthropogenic origin entering it as limited favorable.

The ability to wash out harmful substances and products of their transformation from the atmosphere was estimated using the annual precipitation amount of 676 mm per year for the area under consideration. Such a value of the annual precipitation amount indicates a favorable state of the air basin for the leaching of harmful impurities. The self-cleaning ability of the territory in terms of the degree of dilution of pollutants due to oxygen reproduction was determined by the relative forest cover. The biological productivity, adsorbing and phytoncidal capacity of the forest available in the area under consideration ensure a limited favorable condition of the air basin of the territory under consideration in terms of the degree of dilution of pollutants entering the air basin.

The idea of the level of existing pollution of the air basin of the area under consideration consists of two components, i.e. background atmospheric pollution and the level of anthropogenic pollution. The data on background air pollution in the area under consideration, provided by the Tyumen Center for Hydrometeorology and Environmental Monitoring, indicate that the air basin of the area is most polluted with nitrogen dioxide and carbon monoxide (Table 1).

However, the data on background atmospheric pollution do not fully reflect the current degree of atmospheric air pollution in the area of the gas processing plant location [Regulations on the assessment of the impact of planned economic and other activities on the environment of the Russian Federation. Order of the State Committee for Environmental Protection of the Russian Federation No. 2302 dated 05/16/2000.]. The emissions from existing gas processing plant facilities make a significant contribution to the total load on the air basin. Figure 3 shows the characteristics and parameters of emissions obtained by measuring with the instruments for collecting concentrations of air quality pollutants introduced into the level of total pollution of the air basin of the area under consideration by operating gas processing plant productions [Approximate safe levels of exposure to pollutants in the atmospheric air of populated areas: Hygienic standards, 2008].

The main sources that make the greatest contribution to atmospheric air pollution at the object under consideration can be distinguished:

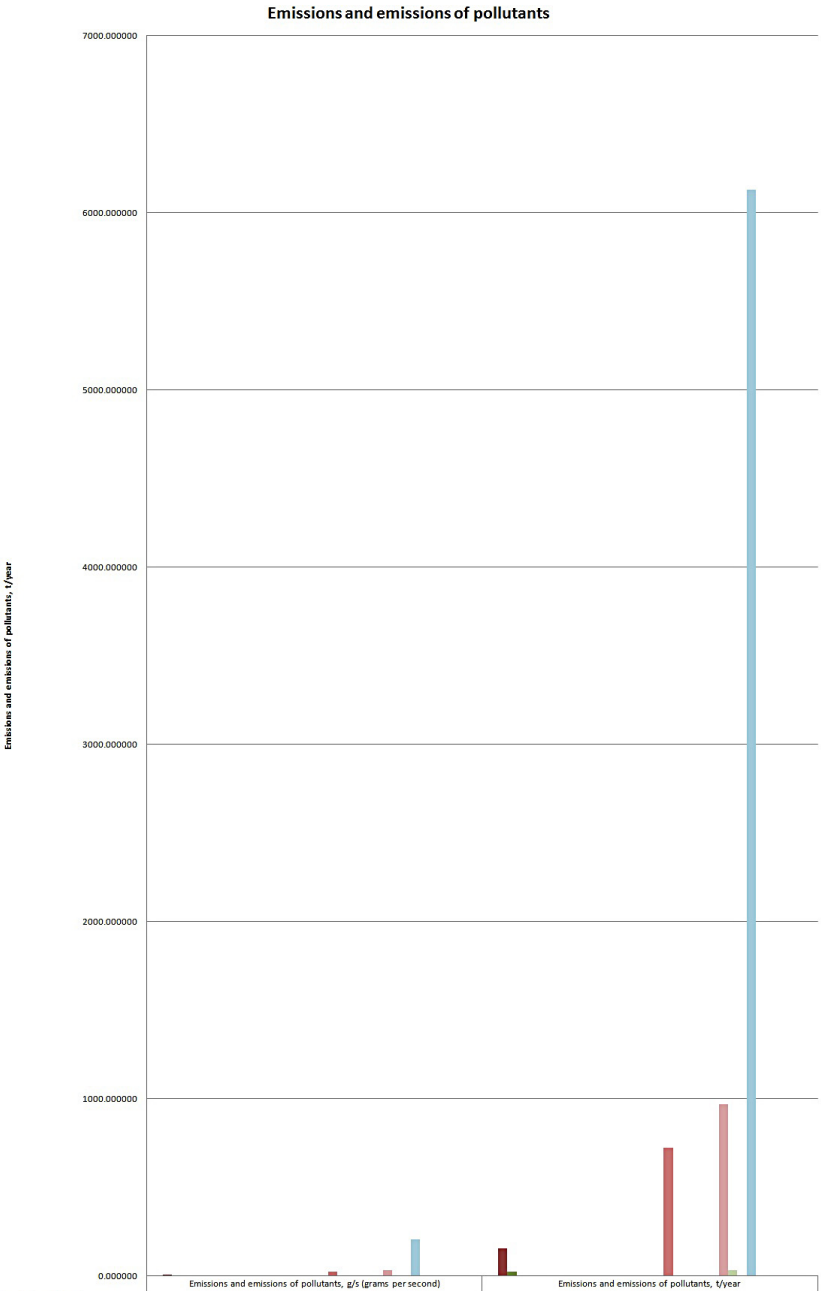
- hydrocarbons of various compositions, mineral oil vapors, ethylene glycol vapors;
- combustion products: carbon monoxide, nitrogen oxides, hydrocarbons, soot;
- iron oxides, manganese oxide, silicon oxide, carbon monoxide, nitrogen dioxide and abrasive dust, wood dust.

The intake of pollutants into the air basin of the gas processing plant's location area currently comes from the facilities of the main and auxiliary production facilities that ensure the technological cycle of its operation. The chemical composition of pollutants released into the air basin depends on the source that carries out such an emission. The contribution of the facilities of the gas processing plant to the existing pollution of the air basin of the area under consideration is significant, as evidenced by the total volume of gross emissions of pollutants from the existing production facilities of the gas processing plant. The list and quantity of pollutants entering the atmospheric air during the normal operation of the enterprise at the present time are shown in Figure 4.

In accordance with the data provided, the emission of pollutants into the air basin of the area under consideration from the existing production facilities of the gas processing plant is 8045.5 tons/year. Moreover, the largest contribution to the gross emission of pollutants is made by the emissions of carbon monoxide, marginal hydrocarbons, soot and nitrogen oxides.

Table 1. Characteristics of background pollution of the air basin

Name of harmful substances	MPC mg/m^3	Background concentrations of substances	
		mg/m^3	Fraction of MPC
Nitrogen dioxide	0.200	0.050	0.25
Sulfur dioxide	0.500	0.015	0.03
Carbon monoxide	5.000	1.500	0.30



	Emissions and emissions of pollutants, g/s (grams per second)	Emissions and emissions of pollutants, t/year
2-ethoxyethanol	0.002100	0.016100
Nitrogen dioxide	7.270050	155.543210
Nitrogen oxide	1.173240	25.275783
Acetone	0.002100	0.016100
Benz(a)pyrene	0.000001	0.000009
Gasoline	0.004270	0.003200
Butyl Acetate	0.002100	0.016100
Diethylene	0.038300	1.108500
Glycol Iron Oxides	0.204572	1.496257
Kerosene	0.094340	0.259700
Xylene	0.015000	0.250000
Fuel oil ash	0.001600	0.001900
Manganese and its compounds	0.001830	0.019400
Mineral oil	0.068000	0.257865
Mercaptans	0.000021	0.000649
Methanol	3.048800	0.274100
Abrasive dust	0.006422	0.014645
Wood dust	0.063800	0.101200
Inorganic dust SiO 70-20%	0.000280	0.000500
Soot	23.983450	722.595472
Sulfur dioxide	0.235657	4.416122
Hydrogen sulfide	0.000021	0.000175
N-butyl alcohol	0.004000	0.030200
Toluene	0.010900	0.082700
White Spirit	0.015000	0.255400
Hydrocarbons C1 - C5	32.044706	967.233700
Hydrocarbons C6 - C10	0.618091	34.161210
Hydrocarbons C12 - C19	0.005200	0.002200
Carbon Monoxide	205.394400	6129.375000
Carbon dioxide	0.064500	0.053300
Formaldehyde	0.002500	0.001800
Hydrogen fluoride	0.000310	0.001050
Ethylene Glycol	0.155774	3.480400
Chrome (VI)	0.000016	0.000010
Ethanol	0.005300	0.040300

Fig. 3. Characteristics and parameters of emissions

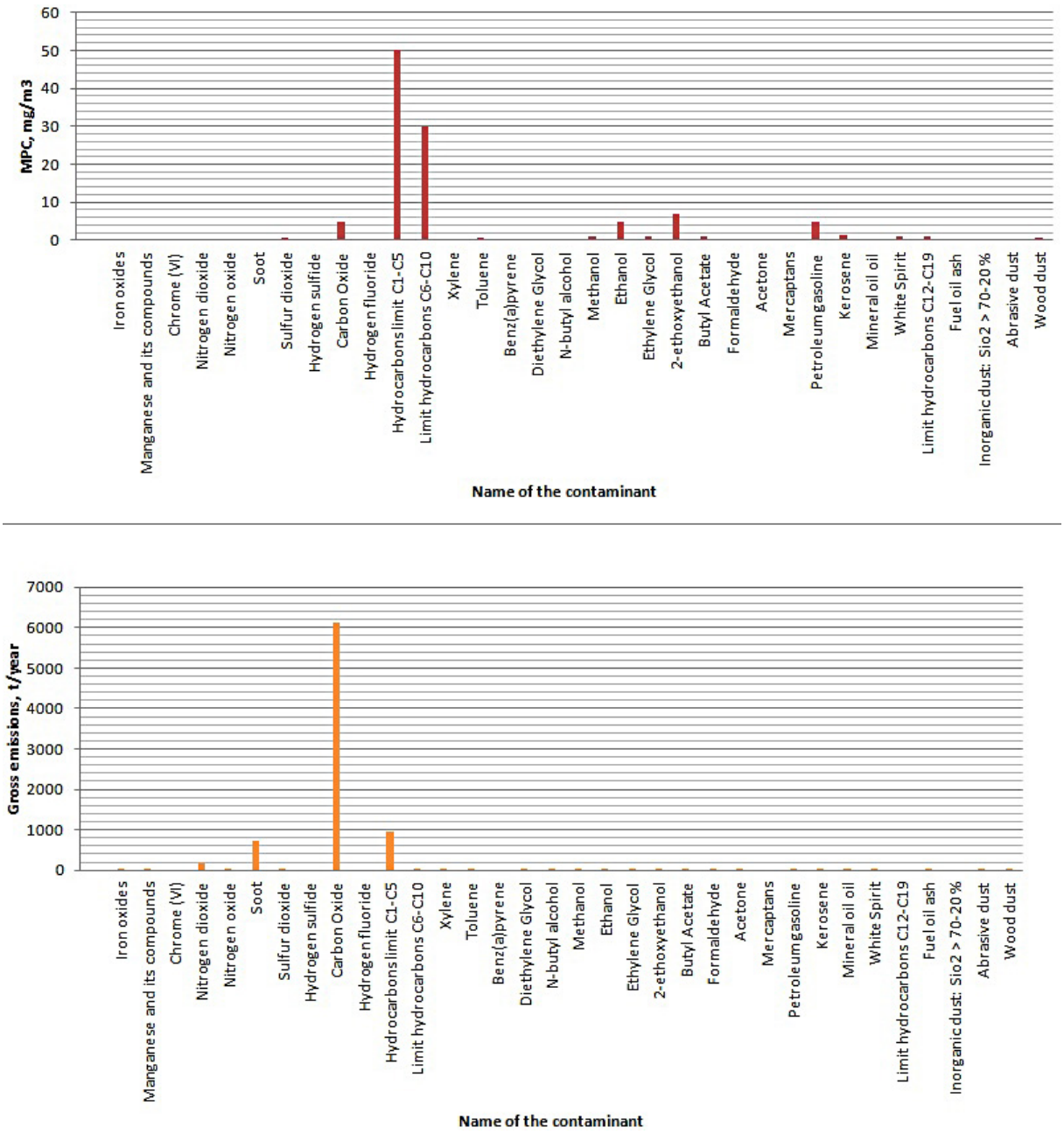


Fig. 4. Characteristics of gross emissions of pollutants from operating facilities of the gas processing plant

RESULTS

To assess the degree of impact of pollutants on the air basin, calculations of the dispersion of these substances in the surface layers of the atmosphere were carried out. Calculations were carried out according to the method of calculating the concentration in atmospheric air of harmful substances contained in industrial emissions [OND-86 Method of calculation of concentrations in atmospheric air of harmful substances contained in emissions of enterprises, 1986], using a unified program for calculating atmospheric pollution under the following initial conditions:

- the dispersion calculation was carried out only for those pollutants the emissions of which will change as a result of the implementation of the planned activity;
- the volumes and parameters of the existing emissions of air pollutants from the existing production facilities of the gas processing plant are shown in Figure 3;
- background concentrations of pollutants were taken in accordance with the data of the Tyumen Center for Hydrometeorology and Environmental Monitoring (Table 1);
- to calculate the dispersion, the boundary of the sanitary protection zone was constructed (Fig. 5);

- the coefficient of expediency of the dispersion calculations is assumed to be 0.01 MPC;
- the calculations took into account the summing effect of sulfur dioxide, hydrogen sulfide, formaldehyde and hydrogen fluoride emitted into the air pool (summation groups: sulfur dioxide – hydrogen sulfide, hydrogen sulfide – formaldehyde, sulfur dioxide – hydrogen fluoride);
- summation effect for two- and four-component mixtures including nitrogen dioxide according to [Maximum permissible concentrations (MPC) of pollutants in the atmospheric air of populated areas: Hygienic standards. GN 2.1.6.1338-03, 2003] was not taken into account for those summation groups for which the specific gravity of the concentration of this substance, expressed in fractions of MPC M.R. is: in a two-component mixture – more than 80%, and in a four-component mixture – more than 60%. Table 2 shows the contributions of nitrogen dioxide to pollution determined for each summation group not taken into account in the calculation;
- the values of the maximum one-time maximum permissible concentrations of pollutants for populated areas (MPC) are taken as the criterion for assessing the degree of impact on the air basin.

The results of the conducted dispersion calculations showed that at present, the concentrations of almost all pollutants released into the air basin from the operating plant facilities in the surface layer of the atmosphere do not reach their maximum permissible level for populated areas, even on the territory of the industrial site of the gas processing plant.

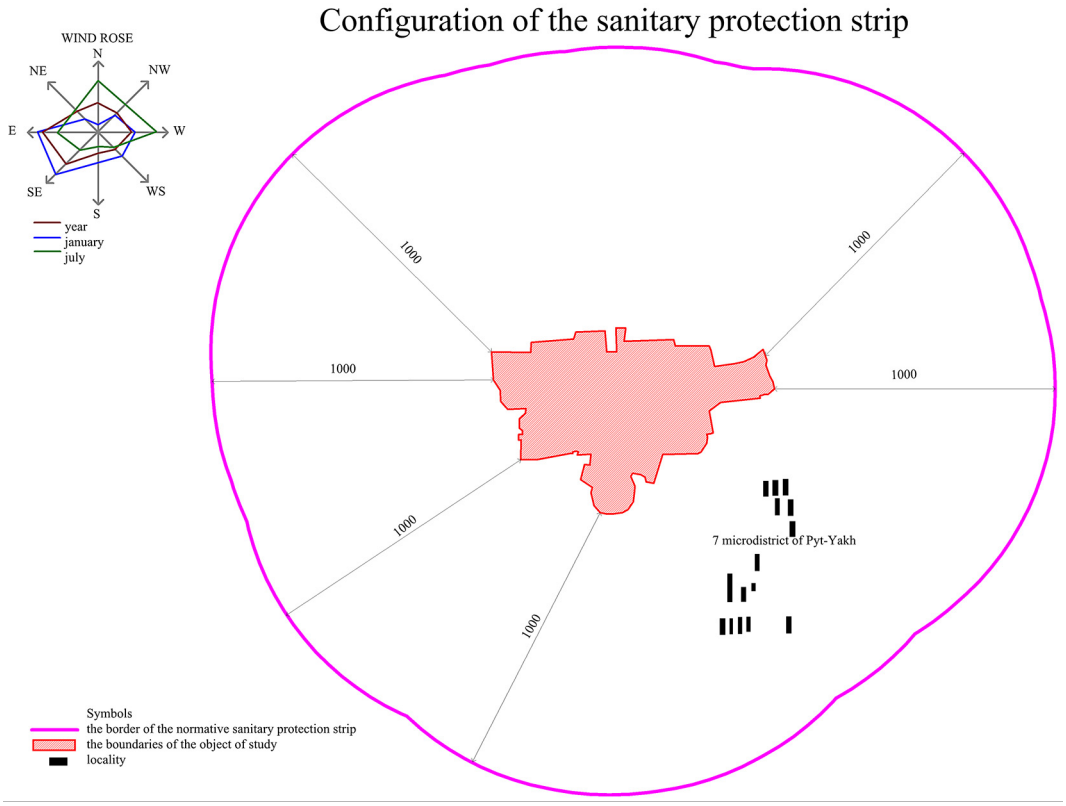


Fig. 5. Border of the sanitary protection zone

Table 2. List of mixtures with no summation effect

Summation group	Surface concentration at the maximum point, fractions of MPC		Proportion of nitrogen dioxide, %
	Nitrogen dioxide	Summation groups	
Nitrogen dioxide + Nitrogen oxide + fuel oil ash + sulfur dioxide	0.83	0. 94	88.30
Nitrogen dioxide + Sulfur dioxide	0.83	0.88	94.32

The exception is methanol emissions (Figure 6), which currently have the greatest impact on the air basin of the area under consideration. The surface concentrations of this substance reach the maximum permissible level for populated areas at a maximum distance of 120 m in the north direction from the border of the industrial site of the gas processing plant. This indicates the presence of a zone of negative impact of existing emissions of the specified substance on the condition of the air basin. However, the zone of such impact is currently limited to the limits of the sanitary protection zone.

To confirm that there is currently no direct dangerous effect of pollutants released into the air basin from the facilities of the main and auxiliary production of the gas processing plant on the health of the population living in the area under consideration, a dispersion calculation was carried out, followed by the determination of surface concentrations at the design points of the sanitary protection zone and residential development. The calculations have shown that the surface concentrations of none of the substances reach their maximum permissible level for populated areas, both at the border of the sanitary protection zone and in residential areas.

CONCLUSIONS

The conducted research has shown that the current impact on the air basin of the considered area of emissions of pollutants from operating industries is limited to the limits of the sanitary protection zone, and the hygienic state of the atmosphere outside the sanitary protection zone and in the residential area it currently complies with the existing sanitary standards for places of compact living population.

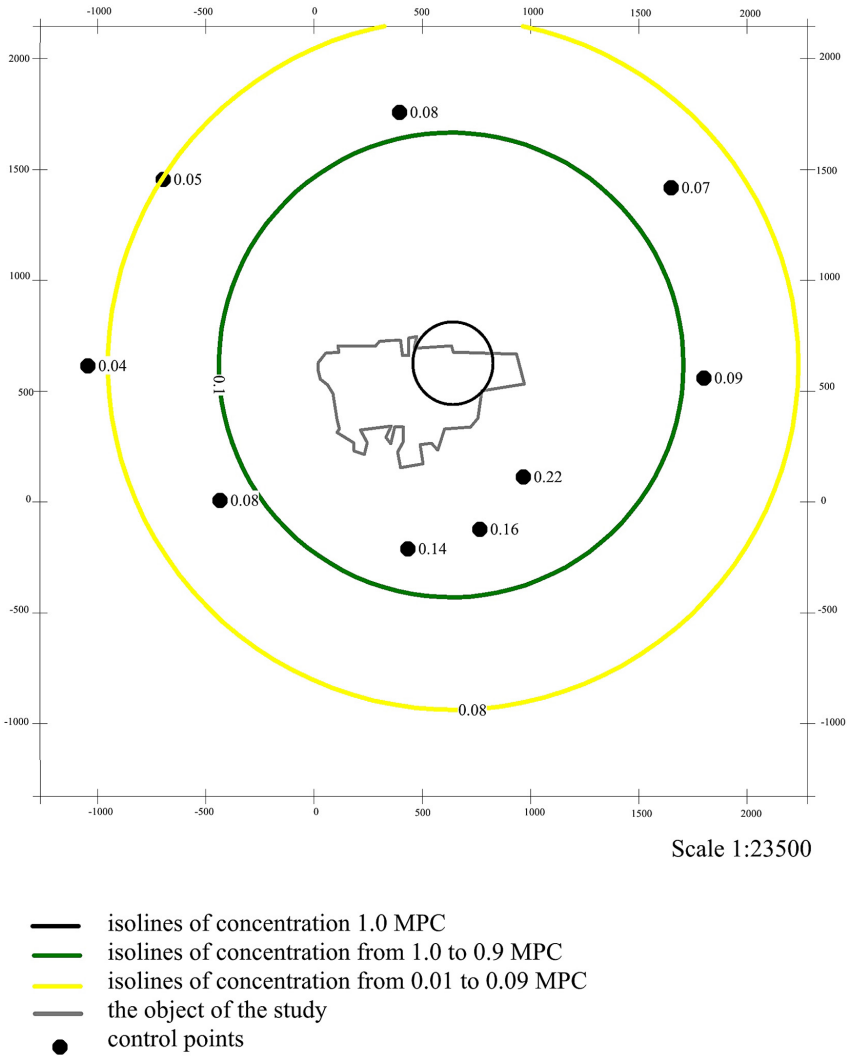


Fig. 6. Map of the concentration fields of methanol (methyl alcohol) in the air pool

On the basis of the above, it can be concluded that the existing state of the air basin of the area under consideration is characterized by: severe climatic conditions, low self-cleaning ability of the air basin, a limited favorable ability to decompose pollutants entering it, a favorable ability to wash out harmful substances and a relatively favorable hygienic condition of the air basin. Thus, the existing state of the air basin of the area of the proposed activity, according to the totality of its determining factors, can be assessed as extremely favorable.

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