УДК 504.3.054
МРНТИ 87.29.23
DOI 10.56525/NMJG2058

STUDY OF THE REASONS FOR THE INCREASE IN THE CONCENTRATION OF HYDROGEN SULFIDE IN ATYRAU

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Abstract. This article is devoted to the study of the causes of exceeding the maximum permissible concentrations of hydrogen sulfide in order to find effective measures to reduce it to ensure the sustainable development and safety of the population of Atyrau. In the context of global climate change and the growth of industrial activity, the problem of emission control is becoming particularly relevant. Existing standards and technical solutions may not always provide the necessary level of environmental protection, which indicates the need to develop new approaches to pollution control and reduction. Thus, the relevance of this study is determined by the need for an in-depth analysis of the causes of atmospheric air pollution by hydrogen sulfide and the development of comprehensive measures to reduce it, which will not only improve the environmental situation, but also create the basis for improving the quality of life of the population, as well as the introduction of innovative methods of environmental risk management in oil-producing regions.

Keywords: hydrogen sulfide, atmospheric air, Atyrau, Republic of Kazakhstan, "AIRkz" application.

Introduction

Modern environmental challenges require special attention, especially to the problems of air pollution in industrially dynamically developed regions. The city of Atyrau, which is one of the largest centers of the oil industry in Kazakhstan, demonstrates a high level of anthropogenic pressure on the environment. One of the most pressing problems in this context is air pollution from hydrogen sulfide released during oil production and refining. An increase in oil production and refining leads to an increase in hydrogen sulfide emissions, which negatively affects air quality. The high concentration of this toxic gas negatively affects the health of the local population, contributing to the development of respiratory diseases and deterioration of general health. In addition, hydrogen sulfide negatively affects the ecosystem of the region, disrupting the balance of natural processes and reducing biodiversity.

Research methods

The following materials were used in the work:

- literary and cartographic sources on atmospheric air components;
- results of Field Research;
- Data obtained through the "AIRkz" application;
- materials of state statistics;
- research of scientific and scientific-production organizations.

To analyze the dynamics of pollution, diagrams were compiled showing changes in the concentration of hydrogen sulfide at stations from September 2024 to February 2025.

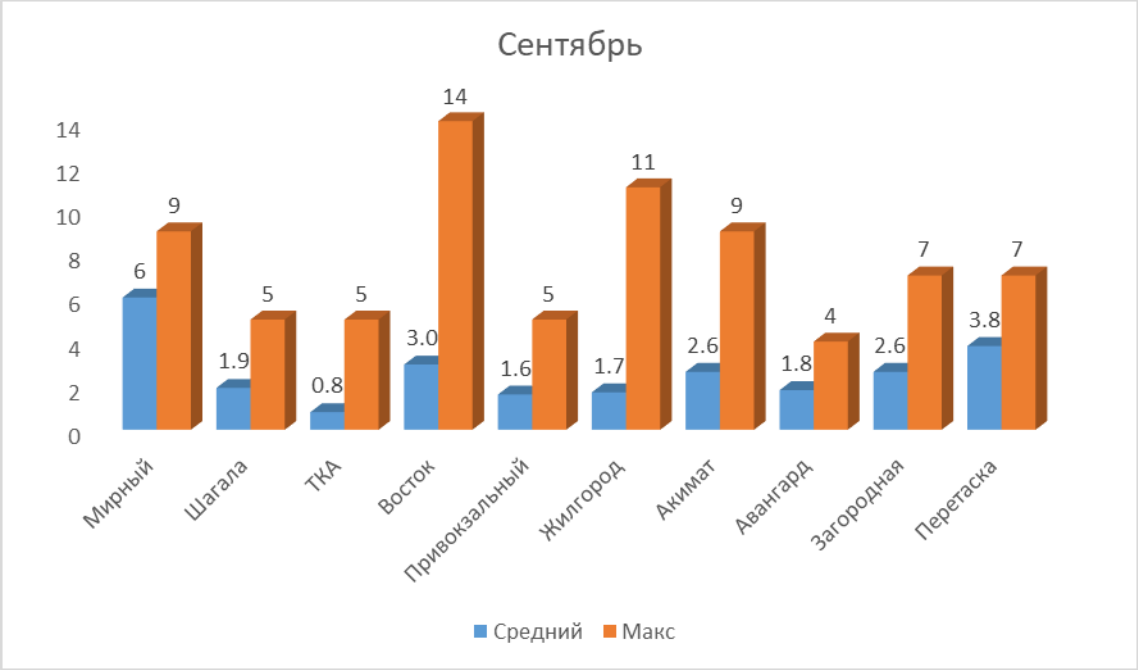

Figure 1 - Temporal dynamics of hydrogen sulfide (H_2S) concentrations at environmental monitoring posts, October 2024.

In October 2024, as in September, the highest average concentrations of hydrogen sulfide were recorded at the Mirny and Peretaska monitoring stations. At the Peretaska station, the average value remained unchanged (3.6 μg/m³), while at Mirny a slight decrease was observed - 5.9 μg/m³ (0.1 μg/m³ lower compared to September) [4].

A similar decrease in average concentration was observed at the following stations:

- "Shagala" - from 1.9 to 1.6 μg/m³ (a decrease of 0.3 μg/m³),
- "Akimdik" - from 2.3 to 1.6 μg/m³ (a decrease of 0.7 μg/m³),
- The most significant reduction in hydrogen sulfide concentration was recorded at the "Vostok" station - from 3.0 to 2.0 μg/m³ (a decrease of 1.0 μg/m³).

In contrast, an increase in average values was observed at the "Zhilgorod", "Avangard" and "Zagorodnaya" stations.

- "Privok": from 1.6 to 2.5 μg/m³,
- "Zhilgorodok": from 1.7 to 2.0 μg/m³,
- "Avangard": from 1.7 to 1.8 μg/m³,
- "Zagorodnaya": from 2.6 to 2.7 μg/m³.

Despite relatively stable average indicators, 17 cases of exceeding the maximum permissible concentration (MPC) were recorded in October, which is four times higher compared to September. The highest hydrogen sulfide concentration was observed at the "Vostok" station, reaching 56 μg/m³, significantly surpassing the values of the previous month. Such an increase may indicate a sharp and short-term rise in pollutant concentrations, which, in turn, requires additional analysis to identify the underlying causes and contributing factors of this considerable growth.

Analysis of MPC passes by the hour

Table 1 cases of exceeding the MPC in October 2024

MONITORING STATION	DAY	Hydrogen sulfide concentration in mcg/m³	MPC exceedance factor (8 µg/m³)	POLLUTION TIME	DIRECTION AND SPEED
NCOC No.109 VOSTOK	02.10.2024	19	2,4	19:20-21:40	E 3 m/s
NCOC No.110 PRIVOKZALNY	02.10.2024	16	2,0	21:40-22:20	ESE 3 m/s
NCOC No.112 AKIMDIK	02.10.2024	9	1,1	20:20-21:20	E 3 m/s
NCOC No.110 PRIVOKZALNY	06-07.10.2024	34	4,3	23:20-05:20	SE 1 m/s
NCOC No.103 SHAGALA	07.10.2024	34	4,3	01:20-04:20	Windless
NCOC No.108 TKA	07.10.2024	12	1,5	04:20-05:20	SE 2 m/s
NCOC No.109 VOSTOK	07.10.2024	56	7,0	01:20-09:40	E 1 m/s
NCOC No.111 ZHILGORODOK	07.10.2024	16	2,0	02:40-04:20	Windless
NCOC No.112 AKIMDIK	07.10.2024	22	2.8	01:40-03:40, 09:00-10:00	Windless
NCOC No.113 AVANGARD	07.10.2024	10	1.3	03:00-04:20	Windless
NCOC No.114 ZAGORODNAYA	07.10.2024	20	2,5	01:40-06:00	ESE 1 m/s
NCOC No.103 SHAGALA	08-09.10.2024	10	1.3	23:20-01:20	NW 2-3 m/s
NCOC No.109 VOSTOK	08.10.2024	12	1.5	22:20-23:00	NW 2-3 m/s
NCOC No.110 PRIVOKZALNY	08-09.10.2024	24	3,0	22:00-01:20	NW 2-3 m/s
NCOC No.112 AKIMDIK	09.10.2024	13	1,6	01:00-01:20	NW 2-3 m/s
NCOC No.114 ZAGORODNAYA	08-09.10.2024	36	4,5	20:20-01:40	NW 2-3 m/s
NCOC No.109 VOSTOK	31.10.2024	13	1.6	08:00-09:40	NW 1 m/s
NCOC No.110 PRIVOKZALNY	31.10.2024	11	1,4	08:40-09:40	NW 1 m/s
NCOC No.114 ZAGORODNAYA	31.10.2024	10	1,3	06:40-09:40	NW 1 m/s

In October 2024, an excess of hydrogen sulfide over MPC (MPC) was recorded in Atyrau for 6 days.

The first pollution episode was recorded on October 2 at the “Vostok” (19 µg/m³), “Privokzalny” (16 µg/m³), and “Akimdik” (9 µg/m³) stations. The timing of MPC exceedances at these stations varied slightly: the initial pollutant detection occurred at the Vostok station, which is associated with its

proximity to the Sasyksai evaporation site. The pollution subsequently spread to the Privokzalny and Akimdik stations.

Analysis of a combination of factors, including wind direction, confirms that the most likely source of pollution is the evaporation of hydrogen sulfide from a stinking ravine. This is also confirmed by the fact that at stations where the wind direction does not coincide with the location of the source of pollution, an excess of MPC is not recorded (see heat map) [7].

In addition, the increase in the concentration of hydrogen sulfide was stopped a few hours after the start, which may be due to a change in the direction of the wind to the North, which contributed to the scattering of pollutants.

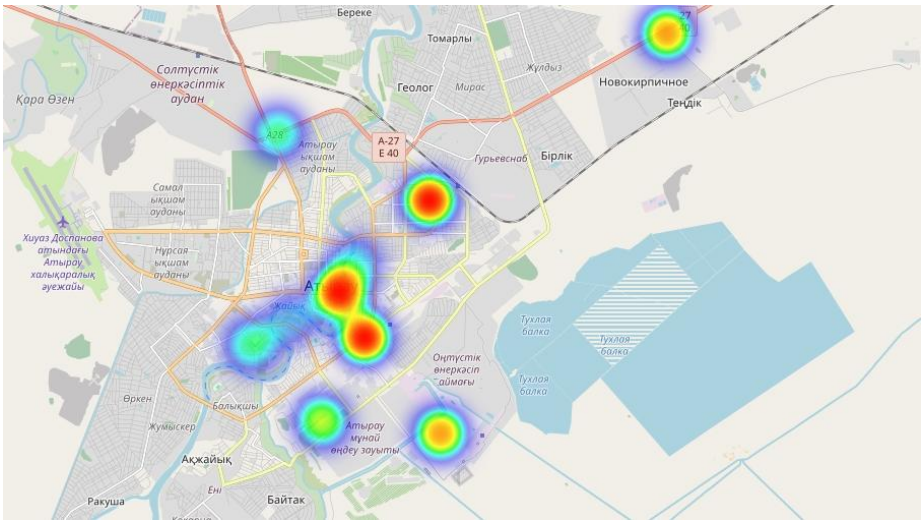

Figure 2. Heat Map of pollution October 2, 2024

The second pollution episode, observed on October 6-7, was the most extensive event within the six-month monitoring period. Exceedances of the maximum permissible concentration (MPC) of hydrogen sulfide were recorded at almost all stations, with the exception of the Peretaska, Khimposelok, and Mirny stations, where elevated background levels were observed but did not surpass the MPC [3,5].

The pollution episode began on October 6 at 23:20 at the Privokzalny station, where the hydrogen sulfide concentration reached 34 μg/m³. Two hours later, on October 7 at 01:20, exceedances were also recorded at the following stations:

- “Shagala” - 34 μg/m³,
- “Zagorodnaya” - 20 μg/m³,
- “Akimdik” - 22 μg/m³,
- “Vostok” - 56 μg/m³ (the highest value recorded on that day).

At the remaining stations, exceedances of the MPC were recorded between 03:00 and 04:00:

- “Zhilgorodok” - 16 μg/m³,
- “Avangard” - 10 μg/m³,
- “TKA” - 12 μg/m³.

Analysis of factors that contribute to pollution

A fairly high concentration of hydrogen sulfide was due to a combination of several factors, primarily meteorological conditions. During the specified period, the region remained under the influence of the anticyclonic Ridge, and clear and warm weather reigned. However, at night, these conditions led to the development of intense temperature inversion, preventing the spread of pollutants

in the vertical direction. As a result, harmful substances were concentrated in the lower layer of the atmosphere.

The following main factors influenced the high concentration of hydrogen sulfide:

- Temperature inversion, which occurred at night, inhibited the spread of emissions, causing them to accumulate in a layer close to the ground.
- A weak wind from the East and its complete suppression in some moments limited the movement of pollutants in the horizontal direction.
- The alignment of the “Sasyksai” site with the prevailing wind direction placed the “Vostok” station in the zone most affected by evaporation, which explains the registration of the highest pollution level (56 μg/m³) at this location.

As a result, the pollution dispersed slowly, first being detected at the Privokzalny station and, after several hours, reaching the central districts of the city. The lowest hydrogen sulfide concentrations were recorded in the western districts and at the more distant “TKA” station, where the pollution only arrived by early morning [7].

Figure 3. The figure shows a thermal map reflecting the spatial distribution of hydrogen sulfide concentration in Atyrau on the night of October 6-7, 2024

The third exceedance of the maximum permissible concentration (MPC) of hydrogen sulfide was recorded in the evening of October 8 and during the night of October 9. The pollution episode began at 20:20 at the “Zagorodnaya” station, located in the northwestern part of the city, where the hydrogen sulfide concentration reached 36 μg/m³ - the highest value recorded among all stations on that day. The most probable cause of this pollution was the “Kvadrat” evaporation area located to the northwest, which is consistent with the wind direction (northwest, weak, 2-3 m/s). The low wind speed facilitated the dispersion of the gas through diffusion.

As shown in the figure (map of the distribution of hydrogen sulfide in Atyrau on October 9, 2024), the pollution was initially localized in the northwestern part of the city, and then gradually spread to other

areas. A few hours later, between 22:00 and 1:00, a high concentration of hydrogen sulfide was recorded in other regions:

- Privokzalny - 24 μg/m³,
- Shagala - 10 μg/m³,
- Vostok - 12 μg/m³,
- Akimdik - 13 μg/m³.

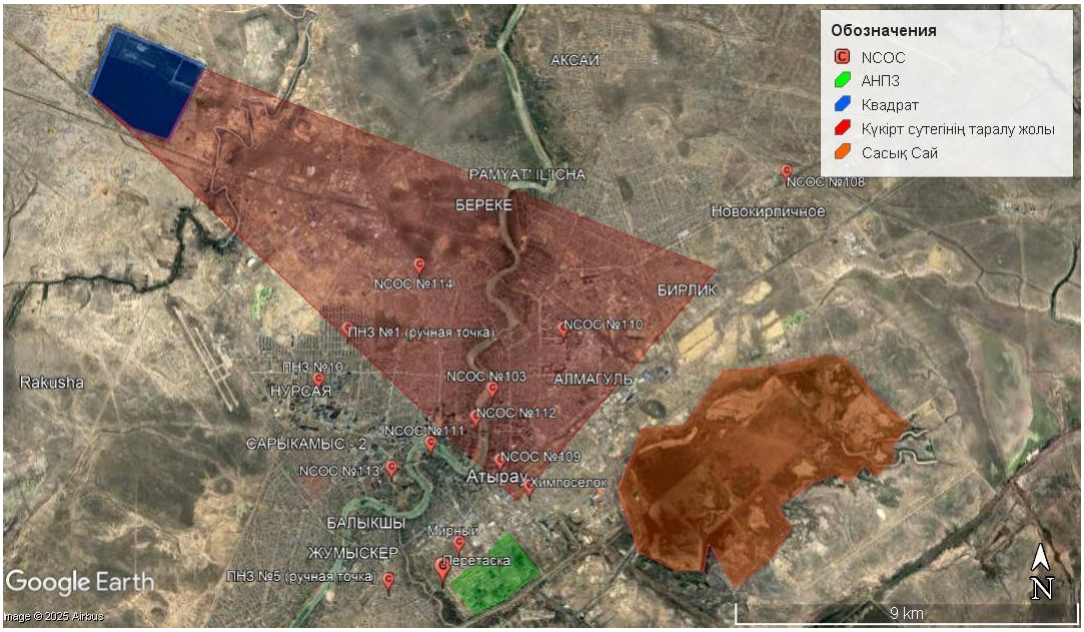

Figure 4. map of the distribution of hydrogen sulfide in Atyrau October 9, 2024

At other stations (Avangard, Zhilgorodok, TKA, etc.), an increase in the concentration of hydrogen sulfide was noted, but no excess of MPC was recorded.

At 01:00 at night, the concentration of hydrogen sulfide decreased, which may be due to increased winds and its change to the North, which contributed to the spread of pollutants. The exception was the Zagorodnaya station, where a high concentration remained until the morning, which may be due to the proximity of the evaporation site [8].

The last case of exceeding the MPC in October was recorded on the 31st. High concentrations were observed at only three stations:

- Vostok - 13 μg/m³,
- Privokzalny - 11 μg/m³,
- Zagorodnaya - 10 μg/m³.

At other stations, no exceeding the maximum permissible concentration was recorded; in some there was a slight increase in concentration to 6-7 μg/m^3 (for example, at Avangard, TKA and Mirny stations).

Pollution at the Zagorodnaya station began at 06:40, when the northwesterly wind in the area was very weak (about 1 m/s). By 08:00 in the morning, the pollution had spread to the “Vostok” and “Privokzalny” stations in the city. The meteorological conditions during this period were highly unfavorable: calm weather was observed, dense fog formed, and a temperature inversion layer trapped pollutants near the ground. However, the exceedance of the MPC did not persist for long-by 10:00 the fog had dissipated, and the warming of the day generated a gradient wind that contributed to the rapid dispersion of harmful substances in the atmosphere [10].

In October 2024, 6 days of excess of MPC of hydrogen sulfide were recorded in Atyrau, which makes this month one of the most polluted during the study period. The highest concentration (56 mcg/m^3) was recorded on October 7 at the Vostok Station.

The analysis revealed several main patterns:

- All cases of MPC exceedance were observed at night and in the morning (between 00:00 and 10:00). This is associated with reduced atmospheric turbulence and nocturnal inversions, which prevent the dispersion of pollutants.
- Weak winds or calm conditions played a significant role in the accumulation of hydrogen sulfide. In most cases, wind speeds did not exceed 2-3 m/s, while during the periods of highest pollution, complete calm was observed.
- The influence of wind on pollution dispersion is evident: easterly and southeasterly winds contributed to the transport of hydrogen sulfide toward the central and northern districts of the city, northwesterly winds carried it toward the southern districts, while westerly and northwesterly winds were associated with elevated concentrations near the “Kvadrat” evaporation field.

The main sources of pollution are likely to be the “Sasyksai” and “Kvadrat” evaporation fields, as well as industrial enterprises. This is confirmed by the recorded exceedances of the maximum permissible concentration (MPC) when winds were directed from these sites. For example, under northwesterly winds, elevated concentrations were observed in the Zagorodnaya and Zhilgorod districts, indicating the influence of the “Kvadrat” site.

In October, the most vulnerable areas were Vostok, Privokzalny, Shagala, Zagorodnaya, and Zhilgorodok, where the most frequent and significant exceedances were recorded.

Thus, the analysis for October 2024 confirms the direct dependence of the level of pollution on meteorological conditions and the location of emission sources. Given the high concentration of hydrogen sulfide in the Earth's crust, as well as its toxicity, the identified samples can be useful for predicting episodes of pollution and developing recommendations to reduce it.

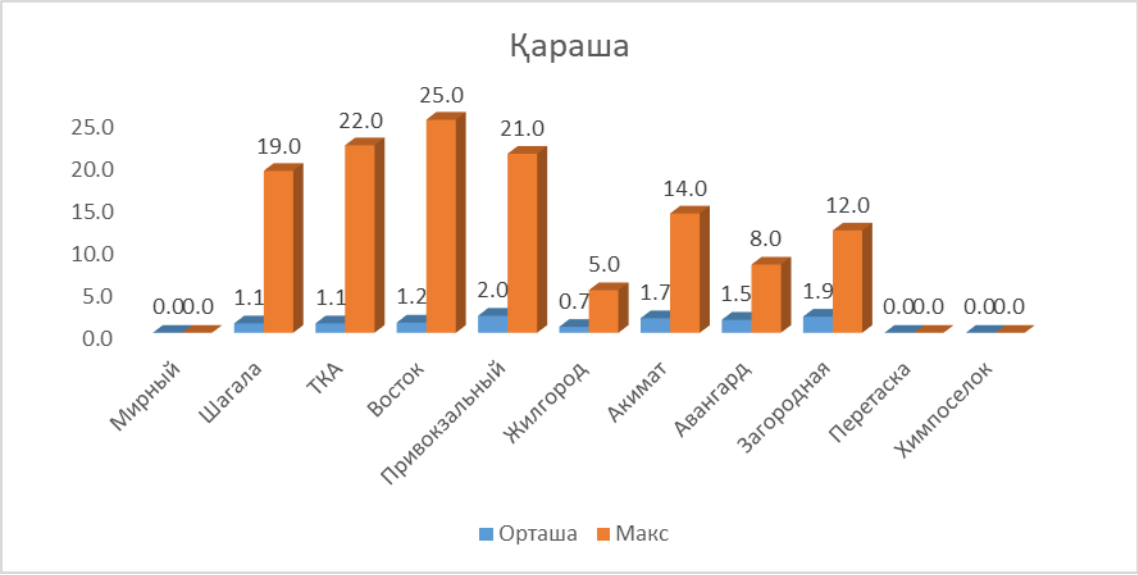

Figure 5. dynamics of hydrogen sulfide concentration in environmental posts in November 2024.

After the events of intense pollution in October 2024, the situation changed significantly in November. In contrast to October, in November, a decrease in the average concentration of hydrogen

sulfide was observed at most stations, the total number of cases of MPC excess decreased, although the localized increase in pollution still persists [9].

There was no information from the Peretaska and Mirny stations - this is due to major repairs at the Atyrau oil refinery. Analysis of average concentrations in November showed a decrease in all stations compared to October. The most pronounced decrease was at the Stations of Zhilgorodok - from 2.0 to 0.7 μg/m^3, "Vostok" - from 2.0 to 1.2 μg/m^3, and at the rest of the ecological posts, the decrease was in the range of 0.3-1.0 μg/m^3.

The peak concentrations in November also changed: no significant exceedances were observed, although 15 cases of MPC exceedance were still recorded, almost at all stations except for Avangard and Zhilgorodok, where no exceedances occurred. The highest maximum values were registered at the Vostok (25 μg/m³), Shagala (19 μg/m³), TKA (22 μg/m³), and Privokzalny (21 μg/m³) stations, while at the other posts maximum concentrations ranged between 1 and 12 μg/m³.

The decrease in hydrogen sulfide concentrations in November is a natural phenomenon, as the cold season of the year is generally unfavorable for gas dispersion. At lower temperatures, water bodies freeze, which weakens the evaporation process and, consequently, reduces the release of hydrogen sulfide into the atmosphere.

Conclusion

The temporal analysis revealed that the majority of MPC exceedances occurred during the night and early morning hours (between 00:00 and 05:00). This phenomenon is associated with unfavorable meteorological conditions such as temperature inversions, calm weather, and fog. A secondary pollution peak was observed in the evening (around 21:00), which also indicates the presence of certain regular patterns.

Thus, the stated objective has been achieved, and the tasks related to spatial and temporal analysis, identification of pollution sources, and assessment of accumulation conditions have been fully addressed. The results of the study are of practical importance and can be used to enhance the effectiveness of the environmental monitoring system, optimize the placement of monitoring stations, and plan measures aimed at reducing harmful substances in the atmospheric air.

In the future, it would be appropriate to conduct additional studies aimed at verifying the reliability of data from areas located near the Atyrau Oil Refinery, as well as assessing the impact of the identified pollution on public health.

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АТЫРАУДАҒЫ КҮКІРТСУТЕК КОНЦЕНТРАЦИЯСЫНЫҢ ЖОҒАРЫЛАУ СЕБЕПТЕРІН ЗЕРТТЕУ

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Аннотация. Бұл мақала Атырау қаласы тұрғындарының тұрақты дамуы мен қауіпсіздігін қамтамасыз ету үшін оны азайтудың тиімді шараларын табу мақсатында күкіртсутектің шекті рұқсат етілген концентрациясының жоғарылау себептерін зерттеуге арналған. Жаһандық климаттың өзгеруі және өнеркәсіптік белсенділіктің өсуі жағдайында шығарындыларды бақылау мәселесі ерекше өзекті болып отыр. Қолданыстағы стандарттар мен техникалық шешімдер әрқашан қоршаған ортаны қорғаудың қажетті деңгейін қамтамасыз ете бермейді, бұл ластануды бақылау мен азайтудың жаңа тәсілдерін әзірлеу қажеттілігін көрсетеді. Осылайша, бұл зерттеудің өзектілігі атмосфералық ауаның күкіртсутегімен ластану себептерін терең талдау қажеттілігімен және оны азайту бойынша кешенді шараларды әзірлеумен анықталады, бұл экологиялық жағдайды жақсартып қана қоймайды.жағдай, сонымен қатар халықтың өмір сүру сапасын жақсартуға, сондай-ақ мұнай өндіруші аймақтарда экологиялық тәуекелдерді басқарудың инновациялық әдістерін енгізуге негіз болады.

Түйін сөздер: күкіртті сутек, атмосфералық ауа, Атырау, Қазақстан Республикасы,"AIRkz" қосымшасы.

ИЗУЧЕНИЕ ПРИЧИН ПОВЫШЕНИЯ КОНЦЕНТРАЦИИ СЕРОВОДОРОДА В АТЫРАУ

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Аннотация. Данная статья посвящена изучению причин превышения предельно допустимых концентраций сероводорода с целью поиска эффективных мер по ее снижению для обеспечения устойчивого развития и безопасности населения города Атырау. В условиях глобального изменения климата и роста промышленной активности проблема контроля выбросов становится особенно актуальной. Существующие стандарты и технические решения не всегда могут обеспечить необходимый уровень защиты окружающей среды, что указывает на необходимость разработки новых подходов к контролю и сокращению загрязнения. Таким образом, актуальность данного исследования определяется необходимостью углубленного анализа причин загрязнения атмосферного воздуха сероводородом и разработки комплексных мер по его снижению, которые позволят не только улучшить экологическую ситуацию, но и создадут основу для повышения качества жизни населения. населения, а также внедрение инновационных методов управления экологическими рисками в нефтедобывающих регионах.

Ключевые слова: сероводород, атмосферный воздух, Атырау, Республика Казахстан, приложение "AIRkz".