UDC 9.91.913
IRSTI 39.25.15
DOI 10.37238/2960-1371.2960-138X.2026.101(1).35

**[1]Mustafina A.*, [2]Inkarova Zh., [3] Emin Atasoy**

**[1,2]L.N. Gumilyov Eurasian National University, Astana, Republic of Kazakhstan**
**[3]Bursa Uludağ University, Faculty of Education, Bursa, Turkey**
***Corresponding-author:** asemgul1985@mail.ru

E-mail: asemgul1985@mail.ru

# MEDICAL AND GEOGRAPHICAL ANALYSIS OF THE EFFECT OF HYDROGEN SULFIDE AIR POLLUTION ON RESPIRATORY DISEASE IN THE POPULATION OF ATYRAU

**Annotation.** The article researches the impact of atmospheric air pollution with hydrogen sulphide on the health of the population of Atyrau. A medical and geographical analysis was conducted, including a comparison of data on hydrogen sulphide concentrations in the atmosphere with respiratory disease incidence rates among different age groups of the population for 2022-2024. For this purpose, samples were taken for research and laboratory analyses were conducted near the five largest industrial facilities in the city. Research has revealed a consistent trend towards exceeding the maximum permissible concentrations (MPC) of hydrogen sulphide in virtually all samples taken in industrial areas of the city, as well as an increase in respiratory diseases, especially among children and adults. The results confirm the existence of a correlation between air quality and public health, which indicates the need to strengthen environmental monitoring and sanitary and hygienic measures in the industrial areas of Atyrau. On the territory of the city, in sanitary and protective zones, it is necessary to carefully carry out: scientifically substantiated measures for landscaping the city, regular prevention of respiratory diseases of the population.

**Keywords:** Atyrau city; hydrogen sulfide; airpollution; sampling points; respiratory diseases; medical and geographical analysis; sanitary protection zone.

*Introduction*

The atmospheric air is a crucial component of the environment, and its quality determines the existence of life on Earth.

The environmental problems of large cities are directly related to the high concentration of industrial enterprises located in relatively small areas. As a result, the fragile ecological balance is disturbed [1].

A variety of investigations over time have confirmed that there is a direct link between emissions of a mixture of pollutants into the atmosphere and a wide range of diseases. However, it is not often possible to link a particular disease to a single pollutant.Generally, health is affected by a complex of detrimental emissions. Therefore, it is essential to explore the nature of these impacts and optimize the management system of the primary mechanism for ensuring the sanitary and epidemiological well-being of the population and the sustainable development of society.

One of the tools involved in the activities of the Kazakhstan sanitary and epidemiological control authorities is social and hygienic monitoring. The main task of this tool is to observe, assess and forecast the health status of the population and the quality of the environment, identify relations between human health and influence of environmental factors, as well as provide data on actual concentrations of chemical substances, exposures and risks for the purpose of adjusting sanitary regulations and risk management [2].

The rapid development of the city of Atyrau in all areas of the economy began during the 1930s, when Kazakhstan was undergoing industrialization. At that time, the foundations of the oil industry were founded, and the first oil production and processing enterprises were constructed. In the post-war years, oil refining, chemical and construction industries developed, contributing to the formation of Atyrau as a major industrial heart of western Kazakhstan [3].

Over the past decades, significant transformations have taken place in the industry of the city of Atyrau: some enterprises have ceased operations, while others have transformed into large oil companies that form the basis of the regional economy. The leading enterprises of the oil and gas complex of the Atyrau region include Tengizchevroil LLP, EmbaMunaigaSJSC, Atyrau Oil Refinery, Caspian Pipeline Consortium LLP, as well as specialized service structures - Rauan-Nalko LLP, Promekologiya LLP, Svetland-Oil LLP, LLP "UBSK" and LLP "Eco-Technics."

The aforementioned companies are the foundation of the region's industrial potential, providing a complete production cycle – from the extraction and processing of hydrocarbon raw materials to their transportation and environmental support. Their operations have a significant impact on the economic development of the Atyrau region and contribute to strengthening Kazakhstan's energy security.

There are more than 70 petroleum companies functioning in the Atyrau region, which account for about 55% of all oil production in Kazakhstan [4].

The growth of the oil and gas industry in Atyrau has contributed to the region's economic growth, but at the same time has led to a deterioration in the quality of the environment and an increase in morbidity among the population. Oil production and processing are accompanied by the release of various chemically active and toxic substances, including hydrogen sulphide. High levels of these substances in the air contribute to the growing incidence of respiratory illnesses among urban populations.

Studies indicate that inhaling hydrogen sulphide released during oil, gas, and organic waste processing is linked to a heightened likelihood of respiratory disorders.Hydrogen sulphide, when inhaled in elevated concentrations, exerts a pronounced irritant effect on the mucous membranes of the eyes and upper respiratory tract, often resulting in symptoms such as coughing, bronchial inflammation, and, in severe cases, pulmonary edema. Prolonged exposure to this compound has been associated with disruptions in central nervous system function and a general decline in physiological health. From an environmental perspective, high atmospheric concentrations of hydrogen sulphide represent a significant toxicological concern, contributing to air pollution and posing substantial risks to public health [5].

**Table 1 – Low concentrations of $H_2S$ in atmospheric air, mg/m$^3$**

| Concentrations of $H_2S$ in atmospheric air, mg/m$^3$ | Impact on humans and description of toxic effects |
|---|---|
| Less than 0.005 | The odour is virtually undetectable, as the concentration remains below the human sensory threshold. At this level, the substance does not exert any harmful effects on health or the environment |
| 0,005 – 0,01 | A faint smell of rotten eggs, noticeable only to particularly sensitive individuals. Safe for short-term exposure |
| 0,01 – 0,03 | The odour is clearly distinguishable; however, short-term exposure does not result in any significant adverse effects |

At these levels, hydrogen sulphide has virtually no hazardous effect on the human body. Its odour may be either imperceptible or barely noticeable. These are safe concentrations, typical of background levels in non-industrial areas. There are no symptoms(Table 1).

**Table 2 – Moderate concentrations of $H_2S$ in atmospheric air, mg/m$^3$**

| Concentrations of $H_2S$ in atmospheric air, mg/m$^3$ | Impact on humans and description of toxic effects |
|---|---|
| 0,03 - 0,2 | The substance has a strong, unpleasant odour reminiscent of rotten eggs. In sensitive individuals, mild irritation of the mucous membranes of the eyes and nose may occur |
| 0,3 – 1,5 | Obvious irritation of the eyes, nose, and throat. Dizziness and nausea may occur with prolonged exposure |
| 1,5 – 5,0 | Irritation of the mucous membranes intensifies, coughing and headaches may occur. Prolonged exposure may cause disruption of the central nervous system |

In this area, the first signs of physiological discomfort appear: irritation of the mucous membranes of the eyes and nose, a slight sore throat. Especially sensitive people may complain of headaches or weakness. Prolonged stay at such concentrations is not recommended (Table 2).

**Table 3 – High concentrations of $H_2S$ in atmospheric air, mg/m$^3$**

| Concentrations of $H_2S$ in atmospheric air, mg/m$^3$ | Impact on humans and description of toxic effects |
|---|---|
| 5,0 – 10,0 | Significant irritation of the eyes and respiratory tract. Breathing difficulties and impaired coordination of movement are possible |
| 10 - 50 | Nausea, dizziness, severe coughing. Prolonged exposure may cause loss of consciousness |

| | |
|---|---|
| 50 - 150 | Potentially dangerous zone: dizziness, confusion, loss of balance occur rapidly |
| 150 - 300 | Severe toxicity, loss of consciousness, convulsions, possible respiratory arrest within 30–60 minutes |

Exposure to such concentration leads to severe irritation of the respiratory tract, cough, headache, and decreased performance. Nausea and dizziness are possible, with prolonged or regular inhalation of such doses, disturbances in the central nervous system are possible (Table 3).

**Table 4 – Very High concentrations of $H_2S$ in atmospheric air, mg/m$^3$**

| Concentrations of $H_2S$ in atmospheric air, mg/m$^3$ | Impact on humans and description of toxic effects |
|---|---|
| 300 - 700 | Extremely dangerous zone: rapid loss of consciousness, possible fatal outcome if exposed for more than 30 minutes |
| More than 700 | Instant loss of consciousness, paralysis of the respiratory centre, possible death within a few minutes |

Serious and dangerous effects, posing a serious threat to health and life. Toxic effects occur rapidly: loss of consciousness, convulsions, respiratory paralysis. At high doses, death may occur within a few minutes (Table 4)[6-7].

*Materials and methods*

A combined array of several sources of official data was used to conduct the study. The information was obtained through social and hygienic monitoring and based on state statistical reports for 2022-2024. The health status of the population was characterized by statistical data on morbidity in the city of Atyrau for specific nosologically forms in different age groups. A study was conducted on the sanitary and hygienic factors of individual facilities that determine the level of safety of the environment (in particular, the state of atmospheric air) and statistical indicators of respiratory morbidity among the population of different age groups.An analytical assessment of atmospheric air pollution levels and their correlation with respiratory disease incidence enabled the quantification of environmental impacts on public health.

The quantitative characteristics of the analyzed data are given below:

• data on child and adult respiratory morbidity (various age groups) for 2022-2024 in Atyrau;

• data from observation posts on hydrogen sulphide chemical concentrations exceeding maximum permissible levels (hydrogen sulphide in the air) for 2024 in Atyrau.

The application of this comprehensive quantitative data provides a reliable basis for identifying causal relationships between hydrogen sulphide concentrations in ambient air and respiratory disease incidence among various population groups in the city of Atyrau.

Sanitary-hygienic and laboratory research methods are used to determine the concentration of hydrogen sulphide in atmospheric air. Instrumental measurements are carried out using gas analysers (e.g. GANK-4, PGF-1, GK-1 and other types), which allow the hydrogen sulphide content to be recorded at various observation points. The results obtained are used to estimate the level of atmospheric air pollution and subsequently compare it with the incidence of respiratory diseases among the population.

Atmospheric air samples were collected between December and February 2024 in the city of Atyrau, including both residential areas and production zones located near potential emission sources.

Data processing was fulfilled using descriptive statistics methods: calculation of average values, fluctuation ranges, and deviations from maximum permissible concentrations (MPC). The regulatory framework used was based on the MPC values approved by the sanitary rules and regulations of the Republic of Kazakhstan, according to which the maximum permissible single concentration of hydrogen sulphide is 0.008 mg/m³, and the average daily concentration is 0.003 mg/m³.

Formaldehyde is included in the list of carcinogenic substances in SanPiN 1.2.2353-08 ‘Carcinogenic factors and basic requirements for the prevention of carcinogenic hazards.’ According to official data from the International Agency for Research on Cancer, a link between formaldehyde, which is used in the production of resins, plastics, paints, textiles, and as a disinfectant and preservative, has been proven to be linked to an increased risk of developing cancerous tumors in the nasopharynx.

With acute inhalation poisoning, formaldehyde causes conjunctivitis, acute bronchitis, up to pulmonary edema. Signs of damage to the central nervous system are gradually increasing. Nitrogen oxides escaping into the atmosphere pose a serious danger to the environmental situation, as they can cause acid rain, and are also toxic

substances in themselves that cause irritation of the mucous membranes. Nitrogen dioxide affects mainly the respiratory tract and lungs and also causes changes in the composition of the blood reduces the content of hemoglobin in the blood.

Specialized literature also points out that exposure to nitrogen dioxide reduces the human body's resistance to disease and causes oxygen deprivation in tissues, especially in children. It enhances the effect of carcinogenic substances, contributing to the development of malignant tumors.

Based on the UN classification, carbon monoxide (II) belongs to hazard class 2.3. The toxic effect of carbon monoxide (II) is due to the formation of carboxyhemoglobin, a significantly more stable carbonyl complex with hemoglobin than the complex of hemoglobin with oxygen (oxyhemoglobin), thus blocking the processes of oxygen transport and cellular respiration. A concentration in the air of more than 0.1% leads to death within one hour.

A high proportion in the atmosphere of substances such as formaldehyde, suspended solids (dust), nitrogen dioxide, carbon monoxide primarily affects the respiratory system, which is in direct contact with the environment and leads to an increase in respiratory pathology, negatively affects the health of the city population [8-9].

*Result and discussion*

The study examined the correlation between atmospheric air pollution levels and the prevalence of respiratory diseases, enabling an assessment of the extent to which environmental conditions affect population health.The graph shows the dynamics of respiratory diseases among the population of Atyrau for 2022–2024. In 2022, the incidence of respiratory diseases was 10,171.4 cases (per 100,000 population). In 2023, the figure increased to 10,538.9, which is 3.6% higher than in the previous year. In 2024, a further increase to 11,556.5 cases was recorded, which is 9.6% more than in 2023 and 13.6% more than in 2022. An analysis of statistical data for 2022–2024 showed a 13.6% increase in the incidence of respiratory diseases among the population of Atyrau. This dynamic indicates a deterioration in the sanitary and hygienic condition of the urban environment, which requires in-depth medical and geographical research and the development of measures to reduce the impact of atmospheric pollutants on public health [10-11].

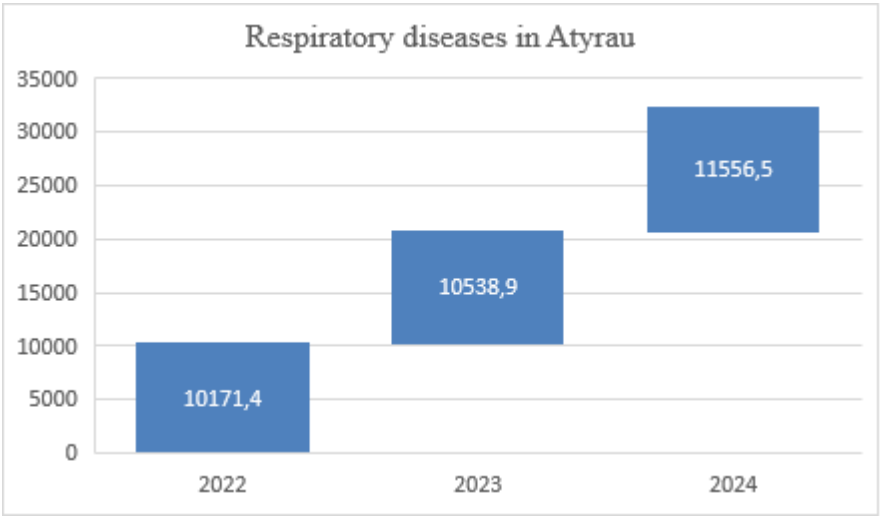


Figure 1 – Dynamics of respiratory diseases among residents of the city of Atyrau

The chart illustrates the trend in respiratory disease incidence among the adult population of Atyrau over the period from 2022 to 2024. In 2022, the morbidity rate was recorded at 7,207.6 cases per 100,000 individuals. A moderate increase was observed in 2023, reaching 7,356 cases, which corresponds to a 2.1% rise compared to the previous year. In 2024, the incidence rate escalated significantly to 8,121.3 cases, reflecting a 10.4% increase relative to 2023 and a 12.7% growth compared to 2022.Throughout the observed period, a consistent upward trajectory in the prevalence of respiratory conditions among the adult population of Atyrau was identified. The most pronounced increase in respiratory diseases among the adult population of Atyrau was observed in 2024, which is probably due to the increased impact of pollutants in the atmosphere, in particular hydrogen sulphide and other industrial emissions.

This hypothesis is supported by data obtained from environmental monitoring stations, which recorded instances of hydrogen sulphide and other chemical concentrations exceeding maximum permissible limits in

Atyrau in 2024. Elevated atmospheric levels of hydrogen sulphide are known to provoke irritation of the respiratory mucosa, weaken immune defenses, and contribute to a rise in respiratory disease incidence.

Therefore, the increase in respiratory disease incidence in 2024 is directly correlated with the deterioration in air quality, which proves the close relationship between the environmental condition and public health.

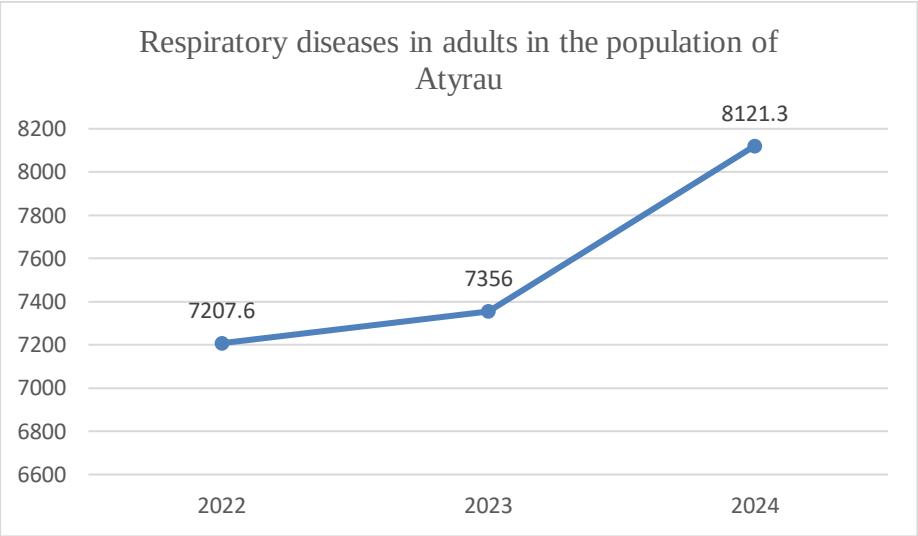


Figure 2 – Incidence of respiratory diseases among the adult population of Atyrau

Unlike the adult population, among adolescents in Atyrau for 2022-2024. there is a decrease in the incidence of respiratory diseases by 34.8%. Such dynamics may indicate a higher physiological stability of this age group, as well as the effectiveness of preventive measures aimed at the health of children and adolescents. However, the findings require additional analysis of environmental factors to identify the reasons for the divergence of trends between different age categories of the population.

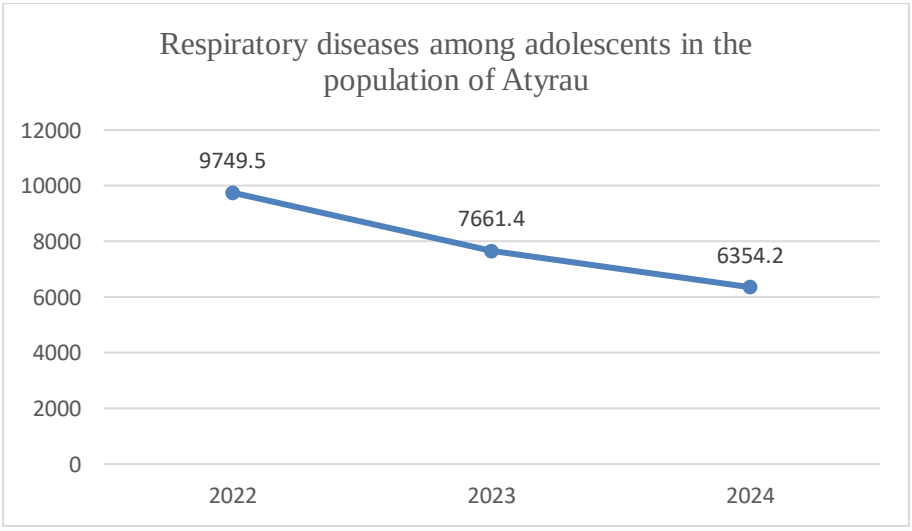


Figure 3 – Incidence of respiratory diseases among adolescents in the city of Atyrau

An analysis of data on respiratory disease incidence among children in the city of Atyrau for 2022–2024 shows a steady upward trend in the number of registered cases. Thus, while 15,545.4 cases of respiratory diseases were recorded in 2022, their number increased to 16,651 in 2023 and reached 18,542.2 cases in 2024. This increase indicates adverse changes in children's health, which may be linked to the deterioration of the environmental situation, in especial the increase in the concentration of pollutants in the atmosphere. Despite compliance with

maximum permissible concentration standards, the Sanitary and Epidemiological Service (SES) highlights that prolonged exposure to air pollutants remains hazardous, particularly for vulnerable groups such as children, pregnant women, the elderly, and individuals with chronic health conditions.

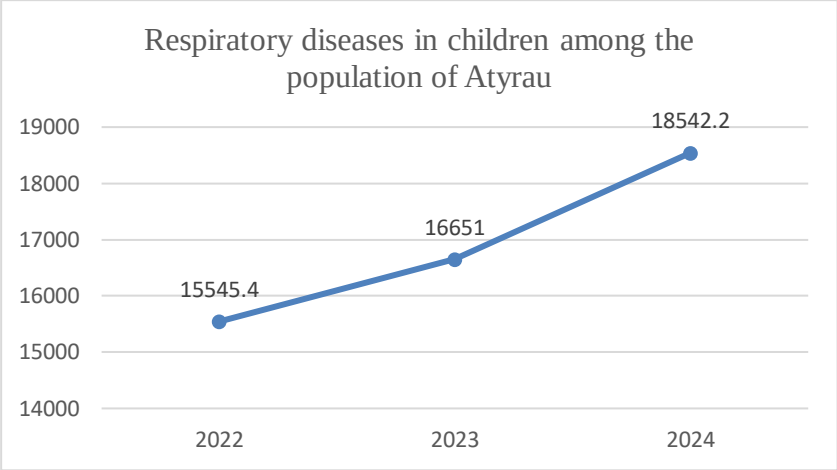


Figure 3 – Incidence of respiratory diseases among children in the city of Atyrau

Air quality monitoring was undertaken in Atyrau at five industrial enterprises and nine busy road intersections. Air quality studies at industrial enterprises were conducted at control and sub-facility points within their areas of influence. The priority atmospheric air pollutants from industrial enterprises include chemicals such as suspended solids (dust), among the primary atmospheric pollutants are sulphur dioxide, hydrogen sulphide, nitrogen oxides (including nitrogen dioxide and nitric oxide), carbon monoxide, and carbon dioxide. These compounds are known for their significant impact on air quality and human health.

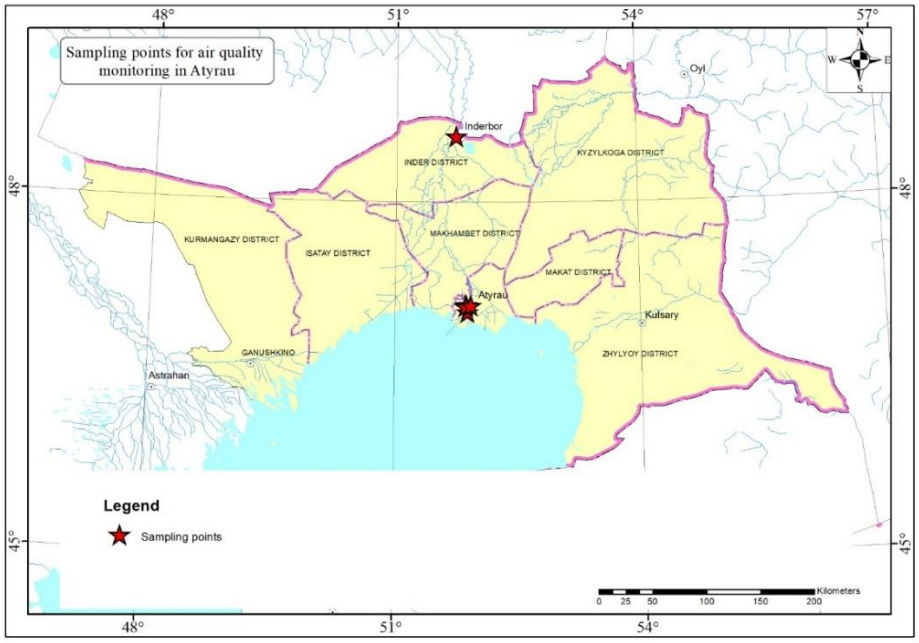


Figure 4 – Map of atmospheric air sampling points in the city of Atyrau

The assessment of hydrogen sulphide ($H_2S$) concentrations in the ambient air over Atyrau during the winter season of 2024 was conducted in line with the methodological guidelines for atmospheric monitoring and the sanitary-hygienic standards of the Republic of Kazakhstan. Observations are carried out three times a day and continuously every 20 minutes [12-13].

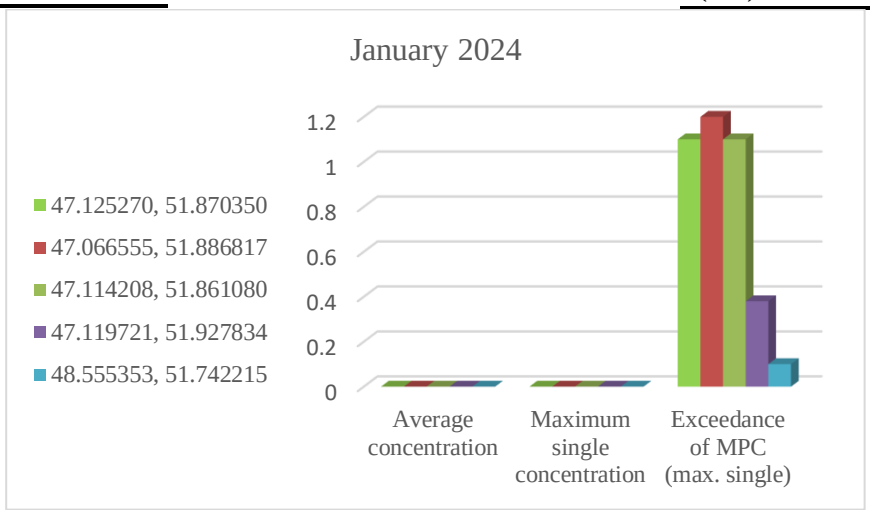


Figure 5 – Average and maximum single concentrations of hydrogen sulphide in air Atyrau city in January 2024

In January 2024, atmospheric air quality monitoring was conducted in Atyrau, focusing on hydrogen sulphide ($H_2S$) content at five control points.

At points 1–3 (47.125271, 51.870349; 47.066554, 51.886817; 47.114208, 51.861079), the average $H_2S$ concentrations were 0.0011–0.0013 mg/m³, and the maximum single concentrations were 0.008–0.010 mg/m³, which exceeds the maximum permissible concentration (MPC) (0.008 mg/m³) by 10–20%. The excess factor was 1.1–1.2, which indicates a slight but recorded exceedance of the permissible levels.

At Points 4 and 5, no exceedances were detected: concentrations ranged from 0.0010 to 0.0030 mg/m³ (10–38% of the MPC), which is within the norm and indicates that the air quality is good. The diagram reflects local exceedances at the first three points and stable indicators at the other two.

Thus, in January 2024, exceeding MPC of hydrogen sulfide was local and insignificant, but further regular monitoring is needed, especially near industrial zones.

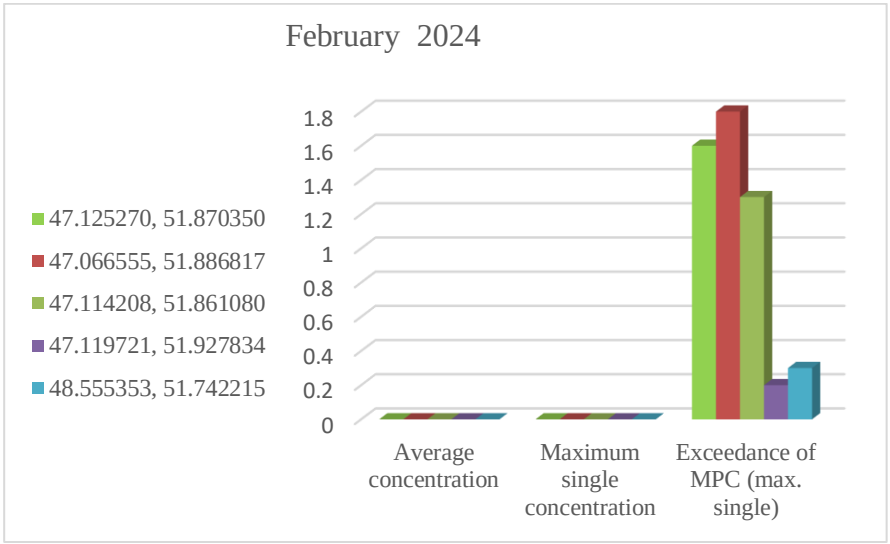


Figure 6 – Average and maximum single concentrations of hydrogen sulphide in the atmospheric air of the city of Atyrau in February 2024

In February 2024, atmospheric air quality monitoring continued in the city of Atyrau, with a focus on hydrogen sulphide ($H_2S$) content. Monitoring covered five control points, where average and maximum single concentrations were determined, as well as the frequency of exceeding the maximum permissible concentration (MPC).

The findings revealed that the highest levels of pollution were recorded at points 1, 2, and 3. At point 1 (47.125270, 51.870350), the average concentration was 0.0031 mg/m³, and the maximum single concentration was 0.0139 mg/m³, which exceeds the maximum permissible concentration by 1.7 times. At point 2 (47.066555, 51.886817), the values reached 0.0033 mg/m³ and 0.0150 mg/m³ respectively, which corresponds to a 1.8-fold exceedance. At point 3 (47.114208, 51.861080), concentrations of 0.0026 mg/m³ and 0.0090 mg/m³ were detected, with a MPC of 1.2. These data indicate a sustained exceedance of permissible limits for a single indicator and the presence of stable sources of emissions in the central and western parts of the city.

At point 4 (47.119721, 51.927834), low indicators were recorded — an average concentration of 0.0006 mg/m³ and a maximum single concentration of 0.0028 mg/m³ (0.35 MPC), which indicates a favorable environmental situation. At point 5 (48.555353, 51.742215), concentrations were 0.0010 and 0.0033 mg/m³ (0.4 MPC). Compared to the previous period, there was an improvement in air quality and a reduced level of pollution.

Overall, the monitoring results for February 2024 indicate the presence of local areas with hydrogen sulphide levels exceeding the standards, mainly in industrial areas of the city. To prevent further pollution, it is necessary to strengthen regular environmental monitoring and analyse potential sources of emissions in order to develop effective strategies and solutions for environmental protection [15-16].

*Conclusion*

An analysis of the spatia+l distribution of hydrogen sulphide in the atmospheric air over Atyrau during the winter seasons of 2022–2024 revealed isolated local zones where episodic exceedances of the maximum allowable single concentration were recorded, indicating changes in the city's atmospheric composition.The highest concentrations were recorded near industrial areas, indicating that the pollution was of technogenic (anthropogenic) origin. The results of the study indicate the need to strengthen environmental monitoring, particularly in areas with high industrial activity, as well as the advisability of expanding the list of controlled pollutants. There are 51 enterprises operating in the city of Atyrau that have an anthropogenic impact on the environment. It is possible to reduce atmospheric pollution through greening and landscaping of sanitary protection zones, as well as strict compliance with established standards for maximum permissible concentrations of pollutants. In accordance with sanitary standards, industrial facilities with a sanitary protection zone of more than 500 m are required to green at least 40% of the territory in the direction of residential development, forming protective plantings of trees and shrubs. However, the actual condition of most such zones does not meet the requirements of regulatory documentation

Concentrations of pollutants, even at low levels, have a negative impact on human health, reducing resilience and contributing to the development of chronic respiratory diseases. The analysis showed that the atmospheric air in Atyrau exceeds permissible standards in some places, and low levels of pollution also pose a long-term risk to public health, as confirmed by the rise in respiratory diseases.

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**Мустафина А., Инкарова Ж., Емин А.**

**МЕДИКО-ГЕОГРАФИЧЕСКИЙ АНАЛИЗ ВЛИЯНИЯ СЕРОВОДОРОДНОГО ЗАГРЯЗНЕНИЯ ВОЗДУХА НА ЗАБОЛЕВАЕМОСТЬ ОРГАНОВ ДЫХАНИЯ НАСЕЛЕНИЯ АТЫРАУ**

**Аннотация.** В статье исследовано влияние загрязнения атмосферного воздуха сероводородом на состояние здоровья населения города Атырау. Проведен медико-географический анализ, включающий сравнение данных по концентрации сероводорода в атмосферном воздухе с показателями заболеваемости органов дыхания среди различных возрастных групп населения за 2022–2024 годы. С этой целью вблизи пяти наиболее крупных промышленных объектов города были отобраны пробы для исследования и проведены лабораторные анализы. Исследованиями выявлена устойчивая тенденция к превышению предельно допустимых концентраций (ПДК) сероводорода практически во всех пробах, отобранных в промышленных районах города, а также отмечается рост заболеваний органов дыхания, особенно среди детей ивзрослых. Полученные результаты подтверждают наличие взаимосвязи между качеством атмосферного воздуха и состоянием здоровья населения, что свидетельствует о необходимости усиления экологического мониторинга и санитарно-гигиенических мероприятий в промышленных зонах Атырау на территории города, в санитарной-защитных зонах необходимо тщательно проводить: научно-обоснованные мероприятия по озеленению города, регулярную профилактику заболеваний органов дыхания населения.

**Ключевые слова:** Город Атырау; сероводород; загрязнение воздуха; пункты отбора проб; заболевания заболевания органов дыхания; медико-географический анализ; санитарно-защитная зона.

**Мустафина А., Инкарова Ж., Емин А.**

**АТЫРАУ ХАЛҚЫНЫҢ ТЫНЫС АЛУ АУРУЛАРЫНА КҮКІРТСУТЕГІМЕН АУАНЫҢ ЛАСТАНУ ӘСЕРІН МЕДИЦИНАЛЫҚ-ГЕОГРАФИЯЛЫҚ ТАЛДАУ**

**Аңдатпа.** Мақалада Атырауқаласы халқының денсаулық жағдайына атмосфералық ауаның күкірттісутегімен ластануының әсеріқарастырылып, зерттелді.2022–2024 жылдарға арналған халықтың әртүрлі жас топтары арасындағы тыныс алу органдары ауруларының көрсеткіштерімен атмосфералық ауадағы күкірттісутегінің концентрациясы туралы мәліметтерді салыстыруды қамтитын медициналық-географиялық талдау жүргізілді. Осы мақсатта қаладағы бес ірі өнеркәсіптік нысанның жанынан зерттеу үшін сынамалар алынып, зертханалық талдаулар жүргізілді.Зерттеулер қаланың өнеркәсіптік аудандарында іріктелген барлық дерлік сынамаларда күкіртсутектің шекті рұқсат етілген концентрациясының (ШРК) артуының тұрақты үрдісін анықтады,сондай-ақ тыныс алу ауруларының,әсіресе балалар мен ересектер арасында өсуібайқалады.Алынған нәтижелер атмосфералық

ауаның сапасы мен халық денсаулығының жай-күйі арасындағы өзара байланыстың болуын растайды, бұл Атыраудың өнеркәсіптік аймақтарында экологиялық мониторинг пен санитарлық-гигиеналық іс-шараларды күшейту қажеттігін көрсетеді. Қалада, санитарлық-қорғау аймақтарында қаланы көркейту бойынша ғылыми негізделген іс-шараларды мұқият жүргізіп, тұрғындардың тыныс жолдары ауруларының алдын алуды жүйелі түрде жүргізу қажет.

**Кілт сөздер:** Атырау қаласы; күкіртсутек; ауаның ластануы; сынама алу бекеттері; тыныс алу аурулары; медициналық-географиялық талдау; санитарлық қорғау аймағы.