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HYDROGEN SULFIDE POLLUTION IN THE ATMOSPHERE OF AN INDUSTRIAL CITY: THE POTENTIAL ROLE OF EVAPORATION FIELDS (ATYRAU, KAZAKHSTAN)

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Abstract. This study assesses atmospheric hydrogen sulfide (H₂S) pollution in Atyrau, Kazakhstan, with a focus on its spatial and temporal variability and the potential role of wastewater-related emission sources. The analysis was based on automatic air-quality monitoring data for the comparable September–February periods of 2021–2022 and 2025–2026. Individual intraday H₂S measurements obtained from the AirKZ monitoring database were aggregated to daily mean concentrations. The upper part of the concentration distribution was characterized using the P95/reference-value ratio, while the frequency of days with daily mean H₂S concentrations above the reference value of 0.008 mg/m³ was used as an additional comparative indicator. During 2021–2022, elevated H₂S levels were observed at both industrial and residential monitoring stations.

The highest P95/reference-value ratio was recorded at the Proparka industrial monitoring station in September 2021, reaching approximately 50. Both the P95/reference-value ratio and the frequency of days with daily mean H₂S concentrations above the reference value were substantially lower during 2025–2026. Statistical analysis confirmed significant differences in daily H₂S concentrations between the two observation periods across all seven monitoring stations included in the comparative analysis. The observed reduction coincided with the reported reduction or suspension of reclamation-related activities. Although the observational design does not allow direct causal attribution, the temporal pattern, spatial distribution, and available literature support the hypothesis that wastewater evaporation fields and sediment disturbance may contribute to elevated atmospheric H₂S levels. The findings emphasize the need to strengthen H₂S monitoring, particularly near wastewater storage facilities and evaporation fields, and to implement targeted environmental monitoring during reclamation and other sediment-disturbance activities.

Keywords: hydrogen sulfide, air pollution, wastewater, evaporation fields, air-quality monitoring, industrial emissions, spatial and temporal variability, Atyrau

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ӨНЕРКӘСІПТІК ҚАЛА АТМОСФЕРАСЫНЫҢ КҮКІРТСУТЕКПЕН ЛАСТАНУЫ: БУЛАНУ АЛАҢДАРЫНЫҢ ЫҚТИМАЛ РӨЛІ (АТЫРАУ, ҚАЗАҚСТАН

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Аннотация: Зерттеуде Атырау қаласының атмосфералық ауасының күкіртсутекпен (H_2S) ластануы оның кеңістіктік және уақыттық өзгергіштігіне, сондай-ақ ағынды сулармен байланысты ықтимал шығарындылар көздерінің рөліне назар аударып отырып бағаланды. Талдау 2021–2022 және 2025–2026 жылдардағы қыркүйек–ақпан аралығындағы салыстырмалы кезеңдерге арналған автоматты ауа сапасы мониторингінің деректеріне негізделді. AirKZ мониторинг дерекқорынан алынған тәулік ішіндегі H_2S өлшемдері тәуліктік орташа концентрацияларға біріктірілді. Концентрациялар таралуының жоғарғы бөлігі Р95/эталондық мән қатынасы арқылы сипатталды, ал H_2S тәуліктік орташа концентрациясы $0,008 \text{ мг/м}^3$ эталондық мәннен асқан күндердің жиілігі қосымша салыстырмалы көрсеткіш ретінде пайдаланылды. 2021–2022 жылдары H_2S деңгейінің жоғары мәндері өнеркәсіптік және тұрғын аймақтардағы мониторинг станцияларында байқалды. Р95/эталондық мәннің ең жоғары қатынасы 2021 жылғы қыркүйекте Propanka өнеркәсіптік мониторинг станциясында тіркеліп, шамамен 50-ге жетті. 2025–2026 жылдары Р95/эталондық мән қатынасы да, H_2S тәуліктік орташа концентрациясы эталондық мәннен асқан күндердің жиілігі де айтарлықтай төмен болды. Статистикалық талдау салыстыруға енгізілген жеті мониторинг станциясының барлығында екі кезең арасындағы тәуліктік H_2S концентрацияларының елеулі айырмашылықтарын растады. Байқалған төмендеу рекультивацияға байланысты жұмыстардың қысқаруы немесе тоқтатылуы туралы мәліметтермен уақыт жағынан сәйкес келді. Алайда зерттеудің бақылаулық сипаты тікелей себеп-салдарлық байланысты анықтауға мүмкіндік бермейді. Уақыттық динамика, кеңістіктік таралу және қолда бар әдеби деректер ағынды сулардың булану алаңдары мен шөгінділердің бұзылуы атмосферадағы H_2S деңгейінің жоғарылауына ықпал етуі мүмкін деген гипотезаны қолдайды. Нәтижелер ағынды суларды сақтау объектілері мен булану алаңдарының маңында H_2S мониторингін күшейту және рекультивация мен шөгінділерді бұзатын басқа да жұмыстар кезінде мақсатты экологиялық бақылау жүргізу қажеттігін көрсетеді.

Түйін сөздер: күкіртсутегі, ауаның ластануы, ағынды сулар, булану кен орындары, ауа сапасының мониторингі, өнеркәсіптік шығарындылар, кеңістіктік және уақыттық өзгергіштік, Атырау

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ИСТОЧНИКИ СЕРОВОДОРОДА В АТМОСФЕРЕ ПРОМЫШЛЕННОГО ГОРОДА: ВКЛАД ПОЛЕЙ ИСПАРЕНИЯ (АТЫРАУ, КАЗАХСТАН)

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Аннотация: В исследовании оценено загрязнение атмосферного воздуха Атырау сероводородом (H_2S) с акцентом на его пространственную и временную изменчивость и потенциальную роль источников выбросов, связанных со сточными водами. Анализ основан на данных автоматического мониторинга качества воздуха за сопоставимые периоды с сентября по февраль 2021–2022 и 2025–2026 годов. Индивидуальные внутрисуточные измерения H_2S , полученные из базы мониторинга AirKZ, были агрегированы до среднесуточных концентраций. Верхнюю часть распределения концентраций характеризовали с использованием отношения P95 к эталонному значению, а частоту дней, в которые среднесуточная концентрация H_2S превышала эталонное значение $0,008 \text{ мг/м}^3$, использовали как дополнительный сравнительный показатель. В 2021–2022 годах повышенные уровни H_2S наблюдались как на промышленных, так и на жилых станциях мониторинга. Максимальное отношение P95 к эталонному значению зарегистрировано на промышленной станции Proparka в сентябре 2021 года и достигало примерно 50. В 2025–2026 годах как отношение P95 к эталонному значению, так и частота дней с превышением эталонной среднесуточной концентрации H_2S были существенно ниже. Статистический анализ подтвердил значимые различия в суточных концентрациях H_2S между двумя периодами наблюдений на всех семи станциях, включённых в сравнительный анализ.

Наблюдаемое снижение совпало по времени с сообщениями о сокращении или приостановке рекультивационных работ. Вместе с тем наблюдательный дизайн исследования не позволяет установить прямую причинно-следственную связь. Временная динамика, пространственное распределение и имеющиеся литературные данные согласуются с гипотезой о том, что поля испарения сточных вод и нарушение донных отложений могут способствовать повышению содержания H_2S в атмосфере. Полученные результаты подчёркивают необходимость усиления мониторинга сероводорода вблизи хранилищ сточных вод и полей испарения, а также проведения целевого экологического мониторинга во время рекультивационных и других работ, связанных с нарушением донных отложений.

Ключевые слова: сероводород, загрязнение воздуха, сточные воды, поля испарения, мониторинг качества воздуха, промышленные выбросы, пространственная и временная изменчивость, Атырау

Introduction. Hydrogen sulfide (H_2S) is one of the key atmospheric pollutants in regions with a well-developed oil, gas, and petrochemical industries. Its high toxicity, distinct organoleptic properties and the ability to have a negative impact on public health and ecosystems necessitate continuous monitoring and regulatory control of its concentrations in the atmospheric air (Kenessary et al., 2017).

Similar difficulties have been noted in oil-producing regions around the world, and distinguishing between industrial and non-industrial sources of hydrogen sulfide remains a key issue for environmental protection and public health.

Oil refineries are traditionally regarded as the main sources of H_2S emissions, primarily associated with hydrocarbon processing, flare combustion and accidental releases. Multiple studies have shown that industrial facilities are a significant source of elevated hydrogen sulfide (H_2S) concentrations in urban areas (Ragothaman and Anderson, 2017; Salih et al., 2023).

Literary review. Furthermore, wastewater treatment and storage systems can represent important sources of H_2S emissions. These systems include evaporation ponds, evaporation fields, and wastewater treatment facilities, where anaerobic decomposition of organic matter can promote H_2S formation (Baawain et al., 2019; Czarnota et al., 2023). Under conditions of open water surface, shallow water depths and disturbance of bottom sediments, these facilities may contribute to atmospheric H_2S emissions (He et al., 2013).

Hydrogen sulfide formation in wastewater storage systems is primarily due to sulfate reduction processes occurring under anaerobic conditions. Sulfate-reducing bacteria use sulfate as the final electron acceptor during the decomposition of organic matter, producing soluble sulfides (H_2S , HS^- , and S^{2-}). The balance between these sulfides is highly dependent on pH and temperature, while high temperatures, shallow water depth, and the mechanical action of bottom sediments facilitate the release of gaseous H_2S into the atmosphere. Therefore, evaporation ponds can become a significant secondary source of sulfur pollution. Hydrogen sulfide pollution is particularly pronounced in Kazakhstan. Kazakhstan is a country with a rich oil and gas industry, which includes

processes with a wide range of hydrogen sulfide emission sources (Ragothaman and Anderson, 2017; Ulman et al., 2026). In addition, many regions face challenges related to aging wastewater infrastructure, outdated treatment technologies, and limited availability of modern wastewater treatment systems (Andraka et al., 2015; Kalmakhanova et al., 2023). Under such conditions, evaporation fields and wastewater storage reservoirs located near settlements may represent additional potential sources of H₂S emissions (Amoatey et al., 2021).

Despite the environmental relevance of this problem, studies addressing the role of wastewater accumulation facilities in atmospheric H₂S pollution in industrial regions of Kazakhstan remain limited. The lack of systematic analyses combining temporal and spatial monitoring data constrains the interpretation of H₂S variability and the identification of potential relationships between observed pollution patterns and different categories of emission sources (Yessenamanova et al., 2021; Ryskalieva et al., 2022).

To date, relatively few studies in Kazakhstan have combined multi-period air-quality monitoring data with spatial information on industrial and wastewater-related potential emission sources. The present study addresses this gap by comparing H₂S monitoring data between two observation periods and examining whether the observed spatial and temporal patterns are consistent with the potential influence of different source categories. The object of the study is atmospheric H₂S pollution in the urban environment of Atyrau, while the subject of the study is the spatial and temporal variability of H₂S concentrations and their relationship with the spatial distribution of potential emission sources.

Wastewater retention facilities, including evaporation ponds and fields, represent potential sources of atmospheric H₂S because anaerobic conditions favor sulfate reduction and sulfide formation. Mechanical disturbance of sulfide-rich bottom sediments during reclamation activities may enhance the release of H₂S into the atmosphere. This mechanism provides a plausible basis for examining whether reclamation-related activities may be associated with episodes of elevated atmospheric H₂S concentrations. The study is based on data from fixed automatic air-quality monitoring stations and applies statistical and comparative methods to characterize temporal and spatial variability in H₂S concentrations, P95/reference-value ratios, and the frequency of days with daily mean concentrations above the selected reference value.

The aim of this study is to compare atmospheric H₂S levels and their spatial and temporal variability in Atyrau during two observation periods (2021–2022 and 2025–2026), using data from fixed automatic monitoring stations, and to evaluate whether the observed pollution patterns are consistent with the potential influence of industrial and wastewater-related emission sources.

To achieve this aim, the following objectives were established:

- to analyze the temporal dynamics of atmospheric H₂S concentrations during the 2021–2022 and 2025–2026 observation periods;
- to characterize the upper part of the H₂S concentration distribution using the P95/reference-value ratio and to assess the frequency of days with daily mean H₂S concentrations above the reference value of 0.008 mg/m³;

- to compare H₂S levels among industrial and residential monitoring stations;
- to statistically evaluate differences in H₂S concentrations between the two observation periods;
- to examine whether the observed spatial and temporal patterns are consistent with the potential influence of industrial and wastewater-related emission sources and meteorological conditions.

The findings of this study have practical implications for improving environmental monitoring strategies, identifying priorities for more detailed source-specific investigations, and supporting H₂S air-quality management in industrial urban areas.

Methods

The area under investigation. The focus of this research is the city of Atyrau (Kazakhstan), located in the lowlands of the Caspian Sea in the western part of the country. As a major center of the petroleum industry, Atyrau has a well-developed oil and gas production and processing infrastructure, which has caused a significant anthropogenic load on the atmosphere (Mustafina et al., 2025). The climate of the region is sharply continental: hot summers and cold winters. During the cold season, reduced air circulation and more frequent temperature fluctuations cause pollutants to accumulate on the surface and exacerbate their spread. According to the official environmental report (RSE Kazhydromet, 2026), major industrial emission sources in Atyrau include the Atyrau Oil Refinery, Tengizchevroil LLP, North Caspian Operating Company N.V., Atyrau Power Plant JSC, Embamunaygas JSC, and West Dala LLP. In addition, there are two wastewater storage ponds located on the leeward sides of the city: the Kvadrat in the northwestern part, and the Tukhlaya Balka evaporation field in the eastern.

In accordance with the Comprehensive plan of socio-economic development of Atyrau region for 2021-2025 reclamation of part of the “Tukhlaya Balka” evaporation field owned by AOR LLP (860 ha) and purification of the sewage evaporation pond “Kvadrat” was planned (Government of the Republic of Kazakhstan, 2022).

Environmental reclamation activities were conducted at the Tukhlaya Balka evaporation field during 2021–2022 as part of the regional environmental remediation program. These activities involved the treatment and disturbance of wastewater-affected areas and bottom sediments. According to the Atyrau Oil Refinery sustainability report, approximately 50% of the planned reclamation work had been completed before the project was subsequently suspended (Atyrau Oil Refinery LLP, 2024). This information was considered when interpreting temporal changes in atmospheric H₂S levels; however, reclamation status was not treated as independent evidence of causality.

To assess the spatial distribution of atmospheric air pollution, a network of monitoring stations is used in various functional areas of the city (including industrial, residential and suburban areas) (Table 1 and 2. Figure 1).

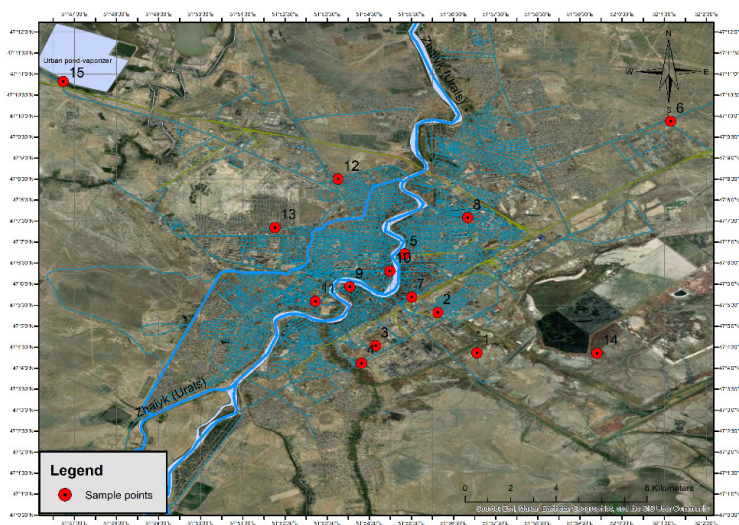
Table 1 — Air-quality monitoring stations considered in the study

	Point title	The location
1	Proparka AOR	47.0726660, 51.9508610
2	Khimposelok AOR	47.0887220, 51.9352780
3	Mirny AOR	47.0754720, 51.9107500
4	Peretaska AOR	47.0685280, 51.9052210
5	POP NCOC No. 103	47.1117740, 51.9221670
6	POP NCOC No. 108	47.1645230, 52.0275220
7	POP NCOC No. 109	47.0947250, 51.9250130
8	POP NCOC No. 110	47.1261730, 51.9472360
9	POP NCOC No. 111	47.0988520, 51.9006170
10	POP NCOC No. 112	47.1050630, 51.9164730
11	POP NCOC No. 113	47.0930470, 51.8869910
12	POP NCOC No. 114	47.1415560, 51.8959480
13	POP No. 17	47.134870, 51.868599

Note: AOR — Atyrau Oil Refinery; POP — Pollution Observation Point; NCOC — North Caspian Operating Company N.V.

Table 2 — Locations of potential H₂S emission sources considered in the spatial analysis

	Point title	The location
1	Tukhlaya Balka evaporation field	47.076043, 51.977329
2	Sewage storage pond "Kvadrat"	47.129827, 51.871184

Figure 1 — Geographical locations of air-quality monitoring stations and potential H₂S emission sources in Atyrau, Kazakhstan.

Data and methods. The comparative analysis included seven monitoring stations with sufficiently comparable data for both observation periods: two stations located in industrially influenced areas (Proparka and Peretaska) and five residential monitoring stations (NCOC No. 103, No. 109, No. 111, No. 112, and No. 113).

The stations provide regular instrumental measurements of pollutant concentrations, including hydrogen sulphide (H_2S). For the purposes of this study, individual intraday H_2S measurements obtained from the AirKZ monitoring database were used. All measurements were expressed in mg/m^3 . For each monitoring station, the arithmetic mean of all valid intraday measurements was calculated for each calendar day, resulting in a time series of daily mean H_2S concentrations used for subsequent statistical analysis. Days without valid measurements were treated as missing data and were excluded from the calculations.

It should be noted that the database was compiled using data obtained via the publicly available online service AirKZ, which may be associated with potential errors in the extraction and aggregation of information. However, the data used are the results of official government monitoring and reflect actual observations.

A data quality control procedure was applied before statistical analysis. Measurements with missing or non-numeric concentration values were treated as invalid and excluded from the calculations. Duplicate records referring to the same monitoring station and measurement time were checked to avoid repeated observations. Extreme H_2S concentrations were not excluded solely on the basis of their statistical magnitude, because unusually high values may represent genuine short-term pollution episodes. When unusually high values were identified, their temporal consistency and, where data were available, observations from neighbouring monitoring stations were examined. Values were excluded only when there was an objective indication of a data-recording or extraction error; otherwise, extreme observations were retained in the dataset. Days without valid measurements were classified as missing data (NA) rather than as zero concentrations. No valid extreme H_2S observations were removed solely as statistical outliers.

To ensure the comparability of results, only those stations for which data were available for both periods under study were included in the comparative analysis. In the partial absence of data, the analysis was limited to overlapping time intervals, which ensured comparability of results between the studied periods.

Monitoring stations were classified into functional categories (industrial impact zones and residential areas) to allow comparative spatial analysis of pollution levels and to identify potential emission sources.

The analysis was performed for the period from September to February in 2021-2022 and 2025-2026, due to the availability of data and allowed for a comparative analysis of atmospheric air pollution.

For reference, the regulatory maximum one-time permissible concentration (MPC) for hydrogen sulfide (H_2S) in ambient air is $0.008 \text{ mg}/\text{m}^3$, according to the Hygienic Standards for Ambient Air in Urban and Rural Settlements and on the Territories of Industrial Organizations, approved by Order No. KR DSM-70 of the Minister of Healthcare of the Republic of Kazakhstan dated 2 August 2022 (Ministry of Healthcare of the Republic of Kazakhstan, 2022). The regulation specifies $0.008 \text{ mg}/\text{m}^3$ as the maximum one-time MPC for H_2S ; a daily average MPC for H_2S is not established. Because the present analysis was based on daily mean concentrations calculated from

individual intraday measurements, comparison of these daily means with 0.008 mg/m^3 was used as a comparative study indicator rather than as a direct regulatory assessment of compliance with the maximum one-time MPC.

The upper part of the H_2S concentration distribution was characterized using the ratio of the 95th percentile (P95) of daily mean H_2S concentrations to the reference value of 0.008 mg/m^3 :

$$P95/MPC = C_{95}/MPC, \quad (1)$$

where C_{95} is the 95th percentile of the daily mean H_2S concentrations calculated from valid intraday measurements. In this study, the P95/reference-value ratio is used as a comparative pollution indicator. Because the denominator represents the regulatory maximum one-time MPC whereas the numerator is derived from daily mean concentrations, this ratio should not be interpreted as a direct regulatory compliance metric.

In addition, the frequency of days with daily mean H_2S concentrations above the reference value was calculated using the following formula:

$$Frequency (\%) = \left(\frac{N_{exc}}{N_{tot}} \right) \times 100, \quad (2)$$

where N_{exc} is the number of days for which the calculated daily mean H_2S concentration exceeded the reference value of 0.008 mg/m^3 , and N_{tot} is the total number of days with valid observations. This indicator represents the frequency of daily mean concentrations above the selected reference threshold and should not be interpreted as the regulatory frequency of exceedances of the maximum one-time MPC.

Descriptive statistics, including the mean, median, and standard deviation, were calculated for each monitoring station and observation period. Differences in daily H_2S concentrations between the 2021–2022 and 2025–2026 observation periods were evaluated separately for each monitoring station using the two-sided Mann–Whitney U test. Only valid daily observations were included in the analysis. The statistical significance level was set at $p < 0.05$, and rank-biserial correlation was calculated as a measure of effect size. To account for multiple comparisons across the seven monitoring stations, p-values were adjusted using the Benjamini–Hochberg false discovery rate procedure. Because consecutive daily observations may exhibit temporal dependence, lag-1 autocorrelation was additionally assessed using Spearman's rank correlation. As a sensitivity analysis, daily H_2S concentrations were aggregated to weekly mean values, and the between-period comparisons were repeated using the Mann–Whitney U test.

Missing days were excluded from concentration-based calculations and designated as “NA”. A value of 0% in the frequency analysis indicates that no daily mean H_2S concentrations above the reference value were recorded among the valid observation days and should not be interpreted as missing data.

Data completeness was assessed separately for each monitoring station and month

as the ratio of the number of days with valid H₂S observations to the total number of calendar days in the corresponding month. Days without valid observations were treated as missing data and excluded from concentration-based calculations. Monthly data completeness, the number of valid observation days, and the number and frequency of days with daily mean H₂S concentrations above the reference value are provided in Supplementary Table S1. Months with no valid observations were designated as “NA” and were not interpreted as zero concentrations or zero frequencies.

The data were visualized using line graphs, bar charts, and heat maps to characterize temporal and spatial variability. Line graphs were used to illustrate monthly changes in the P95/reference-value ratio, bar charts to compare the frequency of days with daily mean H₂S concentrations above the reference value between observation periods, and heat maps to represent the monthly distribution of this frequency across monitoring stations. To improve readability, the residential monitoring stations were divided between two figures.

A logarithmic scale was applied to the P95/reference-value ratios to accommodate their wide dynamic range and improve visualization of both relatively low and high values.

Wind-direction analysis was performed using aggregated city-level meteorological data to examine potential atmospheric transport pathways. Prevailing wind directions were considered in relation to the locations of major industrial facilities and evaporation fields. Days with elevated H₂S concentrations were compared with wind-direction data to identify potential source–receptor patterns. Because station-specific meteorological measurements were unavailable, this analysis was considered exploratory and was not used for definitive source attribution.

Results. The spatial and temporal variability of atmospheric H₂S levels in Atyrau was evaluated using two complementary comparative indicators: the P95/reference-value ratio, which characterizes the upper part of the daily mean concentration distribution, and the frequency of days with daily mean H₂S concentrations above the reference value of 0.008 mg/m³. The analysis covered the comparable September–February observation periods of 2021–2022 and 2025–2026 and included seven monitoring stations representing industrial and residential areas.

The results are presented using monthly P95/reference-value ratios, monthly and period-level frequency indicators, and statistical comparisons of daily H₂S concentrations between the two observation periods..

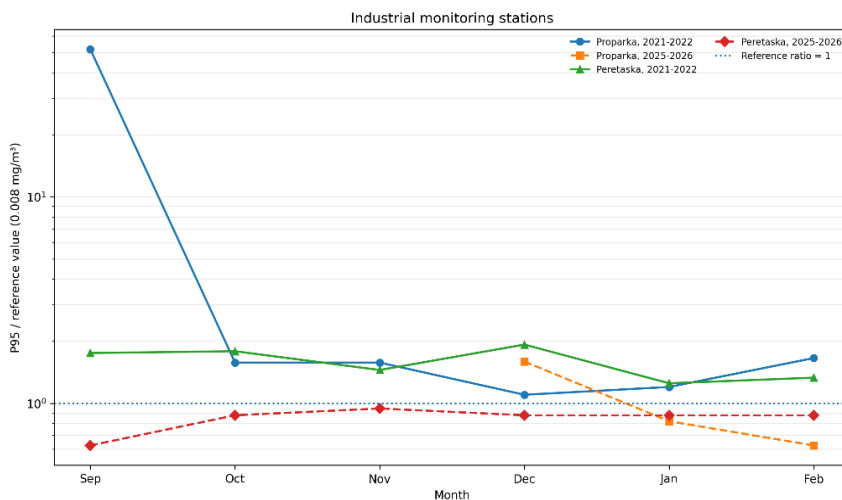


Figure 2 — Monthly P95/reference-value ratio for H₂S at the Proparka and Peretaska industrial monitoring stations during the September–February observation periods of 2021–2022 and 2025–2026. The horizontal reference line at a ratio of 1 indicates that the 95th percentile equals the reference concentration of 0.008 mg/m³. Values below 1 indicate that the 95th percentile was below the reference value and do not exclude isolated higher observations.

Figure 2 presents the monthly ratio of the 95th percentile (P95) of H₂S concentrations to the reference value of 0.008 mg/m³ at the Proparka and Peretaska industrial monitoring stations during the September–February observation periods of 2021–2022 and 2025–2026. A logarithmic scale was used because of the wide range of P95/reference-value ratios.

During 2021–2022, the highest P95/reference-value ratio was observed at Proparka in September, reaching 51.88. This value indicates that the 95th percentile of the H₂S concentration distribution was substantially above the selected reference value during that month. In the subsequent months, the ratio decreased markedly but remained considerably lower than the September value. Peretaska exhibited substantially lower P95/reference-value ratios and a more stable temporal pattern than Proparka.

During 2025–2026, P95/reference-value ratios were generally lower at both industrial monitoring stations than during 2021–2022. At Peretaska, the ratios remained below 1 during most of the observation period. At Proparka, available observations also showed substantially lower ratios than in 2021–2022, although data availability was limited for part of the 2025–2026 period.

Importantly, a P95/reference-value ratio below 1 indicates only that the 95th percentile of the concentration distribution was below the reference value. It does not demonstrate the complete absence of individual observations above 0.008 mg/m³; such events were evaluated separately using the frequency-based indicator.

Overall, the industrial monitoring stations exhibited a pronounced reduction in the upper part of the H₂S concentration distribution during 2025–2026 compared with 2021–2022.

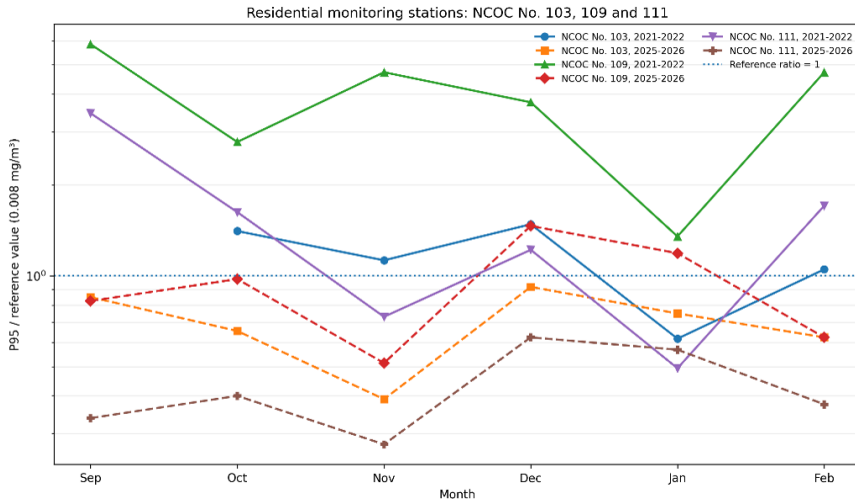


Figure 3 — Monthly P95/reference-value ratio for H₂S at residential monitoring stations NCOC No. 103, No. 109, and No. 111 during the September–February observation periods of 2021–2022 and 2025–2026. The horizontal reference line at a ratio of 1 indicates that the 95th percentile equals the reference concentration of 0.008 mg/m³.

Figure 3 shows the monthly P95/reference-value ratios at the residential monitoring stations NCOC No. 103, No. 109, and No. 111. Pronounced spatial and temporal differences were observed among the three stations and between the two observation periods.

During 2021–2022, NCOC No. 109 showed the highest P95/reference-value ratios among these residential monitoring stations. NCOC No. 111 also exhibited elevated ratios, particularly during the early part of the observation period, whereas NCOC No. 103 generally showed lower ratios and a more stable temporal pattern.

During 2025–2026, the P95/reference-value ratios were substantially lower at all three stations compared with 2021–2022. Most monthly ratios were below or close to the reference ratio of 1, although localized increases remained evident during individual months.

These results indicate a substantial downward shift in the upper part of the H₂S concentration distribution during 2025–2026. However, a P95/reference-value ratio below 1 does not exclude individual observations above the reference value; these events are evaluated separately using the frequency-based indicators presented in Figures 5 and 6

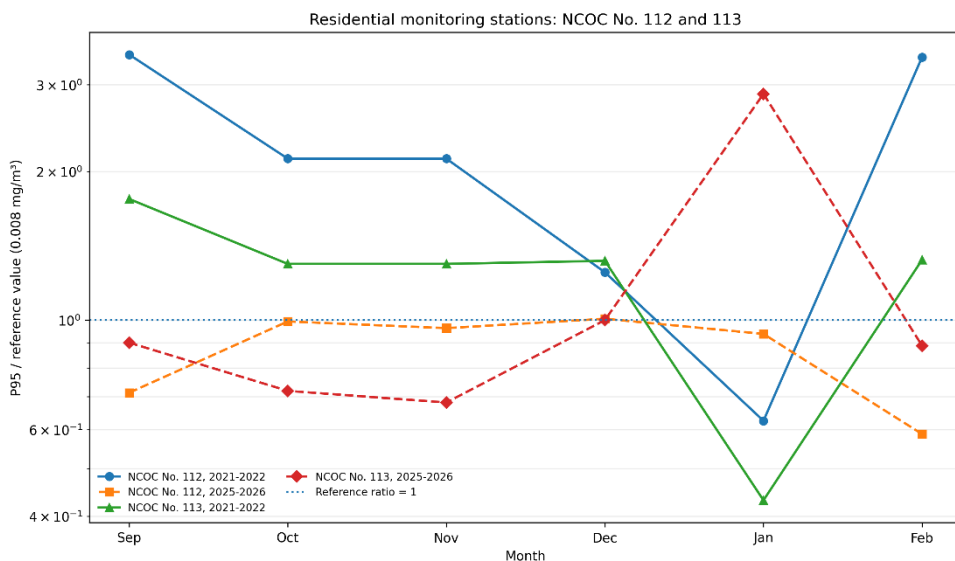


Figure 4 — Monthly P95/reference-value ratio for H_2S at residential monitoring stations NCOC No. 112 and No. 113 during the September–February observation periods of 2021–2022 and 2025–2026. The horizontal reference line at a ratio of 1 indicates that the 95th percentile equals the reference concentration of 0.008 mg/m^3 .

Figure 4 presents the monthly P95/reference-value ratios at residential monitoring stations NCOC No. 112 and No. 113. These stations are presented separately to improve visualization of their temporal patterns.

During 2021–2022, NCOC No. 112 exhibited P95/reference-value ratios above 1 during several months, indicating that the 95th percentile of the H_2S concentration distribution was above the reference value during those months. NCOC No. 113 showed a less pronounced temporal pattern, with ratios varying among months.

During 2025–2026, P95/reference-value ratios were generally lower than during 2021–2022 at both monitoring stations. Nevertheless, localized monthly increases remained evident, particularly at NCOC No. 113, demonstrating that the overall reduction between periods did not eliminate short-term spatial and temporal variability.

Taken together, Figures 3 and 4 demonstrate a general reduction in the upper part of the H_2S concentration distribution at residential monitoring stations during 2025–2026 compared with 2021–2022.

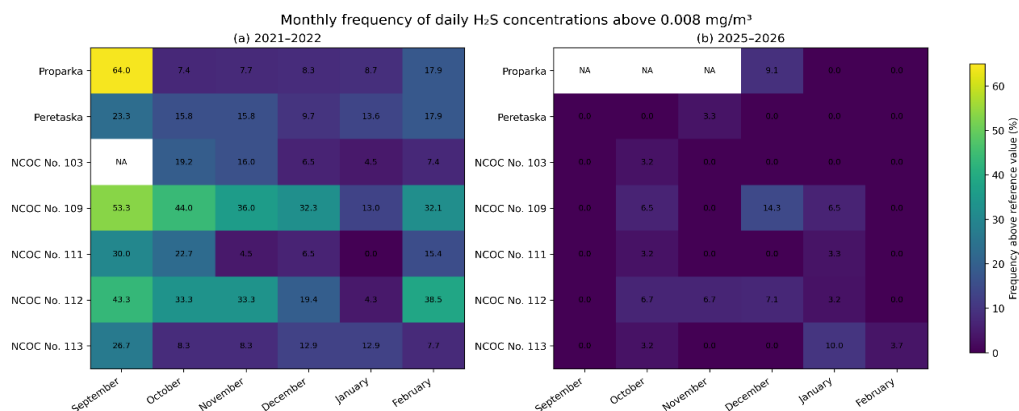


Figure 5 — Monthly frequency (%) of daily mean H₂S concentrations above the reference value of 0.008 mg/m³ at monitoring stations in Atyrau during the September–February observation periods of 2021–2022 and 2025–2026. The color scale indicates the percentage of valid observation days when the daily mean H₂S concentration was above the reference value; “NA” indicates missing data.

The analysis of the monthly frequency of daily mean H₂S concentrations above the reference value of 0.008 mg/m³ (Figure 5) demonstrates pronounced spatial and temporal variability across the monitoring network during the September–February observation periods.

During 2021–2022, relatively high frequencies of days with daily mean H₂S concentrations above the reference value were observed at several monitoring stations. The highest monthly frequency was recorded at Proparka in September (64.0%). High frequencies were also observed at NCOC No. 109 and NCOC No. 112, particularly during the autumn months. Elevated frequencies were additionally observed at NCOC No. 111 and NCOC No. 113, although their temporal patterns differed among months.

At the industrial monitoring stations, Peretaska showed moderate frequencies of daily mean H₂S concentrations above the reference value, with monthly values varying throughout the observation period. Proparka exhibited greater temporal variability, characterized by a particularly high frequency in September 2021 followed by substantially lower values during subsequent months.

Overall, during 2021–2022, higher frequencies were generally observed in autumn (September–November), followed by lower frequencies during the winter months (December–February), although the magnitude and timing of this pattern varied among monitoring stations.

During 2025–2026, the frequency of days with daily mean H₂S concentrations above the reference value was generally lower across the monitoring network. At several stations, no days with daily mean concentrations above the reference value were recorded during individual months, whereas low to moderate frequencies were observed during other months. Localized increases nevertheless remained evident at individual monitoring stations, demonstrating that episodes of elevated daily mean H₂S concentrations persisted despite the overall reduction.

Missing observations are indicated as “NA” in the heat maps and were excluded from the calculation of monthly frequencies. A value of 0% indicates that no daily mean H₂S concentrations above the reference value were recorded among the valid observation days for that station and month and should not be interpreted as missing data.

Comparison of the two heat maps indicates a marked overall reduction in the frequency of days with daily mean H₂S concentrations above the reference value during 2025–2026 compared with 2021–2022. This pattern is consistent with the reduction observed in the P95/reference-value ratio. However, because the analysis is based on daily mean concentrations, these frequencies are interpreted as comparative indicators rather than as direct regulatory frequencies of exceedance of the maximum one-time MPC.

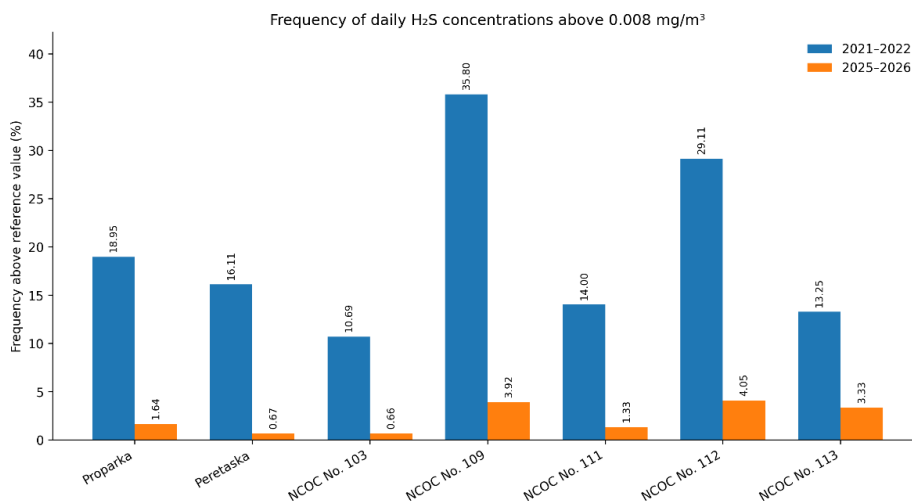


Figure 6 — Comparison of the mean frequency (%) of daily mean H₂S concentrations above the reference value of 0.008 mg/m³ across monitoring stations in Atyrau during the 2021–2022 and 2025–2026 observation periods. Values represent the percentage of valid observation days when the daily mean H₂S concentration was above the reference value.

The analysis of the frequency of daily mean H₂S concentrations above the reference value of 0.008 mg/m³ (Figure 6) revealed substantial differences between the two observation periods.

During 2021–2022, relatively high frequencies of daily mean H₂S concentrations above the reference value were observed at all monitoring stations included in the comparative analysis. The highest frequency was recorded at NCOC No. 109 (35.8%), followed by NCOC No. 112 (29.11%). Elevated frequencies were also observed at Proparka (18.95%), Peretaska (16.11%), NCOC No. 111 (14.00%), and NCOC No. 113 (13.25%), whereas the lowest value was recorded at NCOC No. 103 (10.69%).

During 2025–2026, the frequency of daily mean H₂S concentrations above the reference value decreased at all monitoring stations. The values did not exceed 5% and ranged from 0.66% at NCOC No. 103 to 4.05% at NCOC No. 112.

Thus, the second observation period was characterized by a marked and consistent reduction in the frequency of days with daily mean H₂S concentrations above the reference value across the entire monitoring network. This pattern was observed at both industrial and residential monitoring stations.

The descriptive and statistical comparisons therefore indicate a substantial and consistent reduction in the investigated H₂S indicators between the two observation periods (Table 3).

Table 3 — Statistical comparison of daily H₂S concentrations between the 2021–2022 and 2025–2026 observation periods

Station	n 2021–2022	Median, mg/m ³	n 2025–2026	Median, mg/m ³	U	p	Rank-biserial r
Proparka	153	0.0040	61	0.0020	6543.5	<0.001	0.402
Peretaska	149	0.0050	149	0.0030	17645.0	<0.001	0.590
NCOC No. 103	131	0.0030	152	0.0011	13303.0	<0.001	0.336
NCOC No. 109	162	0.0050	153	0.0020	19850.5	<0.001	0.602
NCOC No. 111	150	0.0030	150	0.0010	18261.0	<0.001	0.623
NCOC No. 112	158	0.0040	148	0.00185	18703.5	<0.001	0.600
NCOC No. 113	166	0.0030	150	0.0018	16685.5	<0.001	0.340

Statistical comparison of daily H₂S concentrations confirmed significant differences between the two observation periods at all monitoring stations. Median daily concentrations were lower in 2025–2026 than in 2021–2022 at each of the seven stations. The Mann–Whitney U test showed statistically significant differences for all station-specific comparisons (all $p < 0.001$). Rank-biserial correlation coefficients ranged from 0.336 to 0.623, indicating differences of varying magnitude among monitoring stations.

Because positive temporal autocorrelation was detected in the daily H₂S series at several monitoring stations, the robustness of the between-period differences was additionally evaluated using weekly aggregated H₂S concentrations. The sensitivity analysis confirmed significantly lower H₂S concentrations during 2025–2026 at all seven monitoring stations. The differences remained statistically significant at Proparka ($p = 0.0079$), NCOC No. 113 ($p = 0.0015$), and at all other monitoring stations ($p < 0.001$). Thus, the observed between-period differences remained evident after reducing the influence of short-term temporal autocorrelation through weekly aggregation.

Overall, the results demonstrate a clear and consistent reduction in both the P95/reference-value ratio and the frequency of days with daily mean H₂S concentrations above the reference value during 2025–2026 compared with 2021–2022. This temporal pattern was observed at both industrial and residential monitoring stations, indicating a broad reduction in atmospheric H₂S levels across the monitored areas of Atyrau. Nevertheless, localized episodes of elevated H₂S concentrations persisted at individual monitoring stations, demonstrating continued spatial and temporal variability in atmospheric H₂S levels.

Discussion. The results showed that there were pronounced temporal differences in atmospheric hydrogen sulfide (H₂S) levels between the two observation periods. During 2021–2022, higher P95/reference-value ratios and a higher frequency of days with daily

mean H₂S concentrations above the reference value of 0.008 mg/m³ were observed, whereas substantially lower values of both indicators were recorded during 2025–2026. A statistical comparison of daily H₂S concentrations also revealed significant differences between the two observation periods at all monitoring stations included in the comparative analysis. Collectively, these data indicate a pronounced temporal shift in atmospheric H₂S levels between the two periods.

At the same time, pronounced spatial variability in atmospheric H₂S levels was observed, with some monitoring stations showing substantially higher values than others. This pattern suggests spatial variability in emission and atmospheric dispersion conditions. The absence of a clear distinction between industrial and residential monitoring stations indicates a complex spatial pattern in which elevated H₂S levels are not confined to areas located close to industrial facilities.

Analysis of pollution episodes in relation to wind direction showed that elevated H₂S levels were frequently associated with south-easterly, southerly, and south-westerly winds. The observed association is consistent with atmospheric transport from sectors containing industrial facilities and evaporation fields. However, because aggregated city-level meteorological data were used, these results should be interpreted as supporting potential source–receptor relationships rather than providing definitive source attribution.

Given the geographical configuration of the study area, the location of wastewater accumulation facilities, and the observed wind directions, evaporation ponds and evaporation fields, particularly the Tukhlaya Balka evaporation field, represent plausible contributors to elevated atmospheric H₂S levels at some monitoring stations. This interpretation is consistent with previously published information for the study area (Atyrau Oil Refinery LLP, 2024) and with studies showing that H₂S may be generated in wastewater storage facilities through anaerobic decomposition of organic matter (Ryskalieva et al., 2022). However, the present analysis does not allow quantitative source apportionment, and the relative contributions of individual industrial and wastewater-related sources cannot be determined from the available data alone.

From a biogeochemical perspective, evaporation fields may function as large anaerobic systems in which the accumulation of organic-rich wastewater promotes sulfate reduction and sulfide formation. Disturbance of bottom sediments during reclamation activities may mobilize dissolved sulfides from deeper sediment layers and facilitate their release into the atmosphere. These mechanisms have been described in wastewater and aquatic systems and provide a plausible process-based explanation for increased H₂S release following sediment disturbance (Baawain et al., 2019; He et al., 2013; Reese et al., 2008).

Elevated H₂S levels observed during 2021–2022 coincided temporally with reclamation activities involving disturbance of bottom sediments. The temporal coincidence between elevated H₂S levels and reclamation activities, together with the known biogeochemical mechanisms of sulfide release from disturbed anaerobic sediments, supports the hypothesis that sediment disturbance may have contributed to elevated H₂S emissions during the 2021–2022 period. However, the observational

design of this study does not allow this association to be interpreted as direct evidence of causality.

The reduction in H₂S levels observed during 2025–2026 coincided with the reported reduction or suspension of reclamation activities. This temporal correspondence is consistent with the proposed hypothesis; however, it cannot independently establish causality because meteorological conditions, industrial operating regimes, wastewater management practices, and other emission sources may also have differed between the two periods. Therefore, the observed reduction should be interpreted as a temporal association rather than as independent evidence that changes in reclamation activities caused the decrease in atmospheric H₂S levels.

The contribution of oil-refining and other industrial sources cannot be excluded. H₂S emissions from oil refineries may vary depending on production processes, operating conditions, accidental releases, and meteorological factors, potentially resulting in localized episodes of elevated atmospheric concentrations (Salih et al., 2023). Therefore, the spatial and temporal patterns identified in this study may reflect the combined influence of several emission sources rather than a single dominant source.

This interpretation is consistent with previous studies indicating that wastewater-related sources may contribute substantially to atmospheric H₂S pollution in industrialized areas. For example, Sanchez et al. (2019) reported elevated H₂S concentrations at monitoring locations farther from a petroleum refinery and closer to wastewater treatment facilities. These findings demonstrate the importance of considering wastewater infrastructure alongside conventional industrial sources when interpreting spatial patterns of atmospheric H₂S pollution.

Several limitations of the present study should be considered. First, the comparative analysis included only monitoring stations for which sufficiently comparable observations were available during both study periods, whereas the original monitoring network comprised a larger number of stations. Reduced spatial coverage may result in areas with insufficient instrumental monitoring and may limit the detection and characterization of localized H₂S pollution episodes.

Second, data completeness varied among monitoring stations and months. Missing observations were excluded from the calculations, but periods with reduced data completeness may be less representative of the full temporal variability of H₂S pollution. Therefore, results for station–month combinations with limited data availability should be interpreted with caution.

Third, the use of aggregated city-level meteorological data limits the accuracy of source–receptor attribution. Although the observed wind-direction patterns are consistent with transport from sectors containing potential H₂S sources, more definitive source attribution would require local meteorological measurements, including wind speed and direction, source-specific emission data, atmospheric dispersion or trajectory modelling, and, where possible, chemical or isotopic source markers.

Fourth, the comparison of the 2021–2022 and 2025–2026 periods represents an observational before–after comparison rather than a controlled experiment. The observed differences between the two periods alone do not establish a causal relationship.

with changes in any specific emission source. Interannual differences in meteorological conditions, industrial operating regimes, wastewater management practices, and other environmental factors may also have contributed to the observed temporal changes

These limitations do not negate the observed spatial and temporal patterns but define the level at which they can be interpreted. The results demonstrate a substantial reduction in atmospheric H₂S indicators between the two observation periods and support the hypothesis that wastewater accumulation facilities and sediment disturbance during reclamation activities may contribute to elevated H₂S levels. However, quantitative determination of the contributions of individual sources requires additional source-apportionment studies and high-resolution meteorological analysis.

From a practical perspective, the results emphasize the need to strengthen atmospheric H₂S monitoring in Atyrau. Increasing the spatial density of monitoring stations, particularly near wastewater storage facilities, evaporation fields, and major industrial sources, would improve the detection of localized pollution episodes. Targeted monitoring during reclamation and other sediment-disturbance activities is particularly important because such operations may increase the potential for secondary H₂S release.

Future studies should integrate high-resolution local meteorological observations, source-specific emission data, operational information from industrial and wastewater facilities, and atmospheric dispersion or air-mass trajectory modelling. Such an integrated approach would allow the hypotheses identified in the present study to be tested more directly and would provide a stronger basis for quantitative source attribution and environmental management decisions.

Conclusion. The study revealed a pronounced temporal shift in the level of hydrogen sulfide (H₂S) in the atmosphere of Atyrau, characterized by a significant decrease in both the P95/reference-value ratio and the frequency of days with daily mean H₂S concentrations above the reference value of 0.008 mg/m³ between 2025 and 2026, compared to the period from 2021 to 2022. The observed decline was characteristic of both industrial and residential monitoring stations, although local episodes with elevated H₂S levels continued.

The study results demonstrate a pronounced spatial heterogeneity of H₂S levels in the atmosphere across the entire monitoring network. Elevated values were observed at both industrial and residential monitoring stations, which indicates that the spatial distribution of hydrogen sulfide pollution cannot be explained solely by proximity to industrial facilities. It is likely influenced by a combination of factors, such as the location of emission sources and atmospheric transport conditions.

The spatial and temporal patterns identified during the study support the hypothesis that wastewater-related facilities, particularly evaporation fields, may contribute to elevated atmospheric H₂S levels in Atyrau. Known biogeochemical processes of sulfate reduction under anaerobic conditions provide a plausible mechanism for H₂S formation in wastewater accumulation facilities, while disturbance of sulfide-rich bottom sediments during reclamation activities may facilitate H₂S release into the atmosphere. However, the observational design of the study does not allow quantitative source apportionment or definitive attribution of the observed H₂S levels to a single emission source.

Elevated levels of hydrogen sulfide in 2021–2022 coincided in time with land reclamation activities related to the disturbance of bottom sediments, while in 2025–2026, when land reclamation activities were reduced or suspended, significantly lower levels of hydrogen sulfide were observed. This temporal coincidence is consistent with the hypothesis that the disturbance of bottom sediments as a result of land reclamation activities could have contributed to increased hydrogen sulfide emissions in an earlier period. However, this does not constitute proof of a cause-and-effect relationship, since meteorological conditions, operating modes of industrial enterprises, wastewater treatment methods, and other sources of emissions may have differed during these two periods.

The observed wind-direction patterns were consistent with the potential transport of H₂S from sectors containing industrial facilities and evaporation fields toward some monitoring stations. Nevertheless, because the analysis was based on aggregated city-level meteorological data, these observations should be regarded as supporting evidence of potential source–receptor relationships rather than as definitive source attribution.

The study also has limitations related to the spatial and temporal completeness of the monitoring network and the use of aggregated meteorological data. These factors introduce uncertainty into the interpretation of spatial patterns of pollution and the attribution of sources. Future studies should therefore combine high-resolution local meteorological observations, source-specific emission data, information on the operating regimes of industrial and wastewater facilities, and atmospheric dispersion or air-mass trajectory modelling to quantitatively assess the relative contributions of individual H₂S sources.

From a practical point of view, the study results emphasize the need to strengthen monitoring of hydrogen sulfide content in the atmosphere in Atyrau, especially near wastewater storage facilities, evaporation fields, and major industrial sources. Targeted monitoring during reclamation and other sediment-disturbance activities would be particularly useful for assessing the potential occurrence of secondary H₂S emissions and supporting environmentally safe management of wastewater accumulation facilities.

Overall, the study indicates significant temporal and spatial variability in the hydrogen sulfide content in the atmosphere of Atyrau and supports the hypothesis that the observed pollution patterns are due to the combined influence of industrial, wastewater-related, biogeochemical, and meteorological factors. The obtained results serve as a basis for further research into specific sources of pollution and for developing more targeted strategies for monitoring and managing hydrogen sulfide levels in industrial cities.

References

- Amoatey P., et al. (2021) A critical review of environmental and public health impacts from the activities of evaporation ponds. *Science of the Total Environment*. <https://doi.org/10.1016/j.scitotenv.2021.149065> (in Eng.)
- Andraka D., Ospanov K., & Myrzakhmetov M. (2015) Current state of communal sewage treatment in the Republic of Kazakhstan. *Journal of Ecological Engineering*, 16(5). — P. 101–109. <https://doi.org/10.12911/22998993/60463> (in Eng.)
- AtyrauOilRefineryLLP.(2024).OtchetobustoiichivomrazvitiiaAtyrauskogoneftepererabatyvayushchego zavoda za 2023 god [Sustainability report of Atyrau Oil Refinery LLP for 2023]. <https://www.anpz.kz/>

upload/iblock/737/wb5kjtscga734cpxyk4y7x4m3ysbo5uz/Otchet-ob-ustoychivom-razvitiy-ANPZ-za-2023-g..pdf (in Russian).

Baawain M., Al-Mamun A., Omidvarborna H., & Al-Sulaimi I.N. (2019) Measurement, control, and modeling of H₂S emissions from a sewage treatment plant. *International Journal of Environmental Science and Technology*, 16. — P. 2721–2732. <https://doi.org/10.1007/s13762-018-1997-z> (in Eng.)

Beghi S.P., Rodrigues A.C., de Sá L.M., Santos J.M. (2012) Estimating hydrogen sulphide emissions from an anaerobic lagoon. *Chemical Engineering Transactions*, 30. 91–96. <https://doi.org/10.3303/CET1230016> (in Eng.)

Centeno D., Lopez A. G., Palomino A., Taboada J., Sinclair R., Montgomery Q., Marquez C., Sanchez M. N., Arzeno-Soltero I. B., & Freilich M. A. (2025) Hypereutrophication, hydrogen sulfide, and environmental injustices: Mechanisms and knowledge gaps at the Salton Sea. *GeoHealth*, 9(6). e2024GH001327. <https://doi.org/10.1029/2024GH001327> (in Eng.)

Czarnota J., Masłoń A., Pajura R. (2023) Wastewater treatment plants as a source of malodorous substances hazardous to health, including a case study from Poland. *International Journal of Environmental Research and Public Health*, 20(7). — P. 5379. <https://doi.org/10.3390/ijerph20075379> (in Eng.)

Government of the Republic of Kazakhstan. (2022) O vnesenii izmenenii v postanovlenie Pravitelstva Respubliki Kazakhstan ot 21 maya 2021 goda No. 337 “Ob utverzhdenii Kompleksnogo plana sotsialno-ekonomicheskogo razvitiya Atyrauskoj oblasti na 2021–2025 gody” [On amendments to Resolution No. 337 of May 21, 2021 on the Comprehensive Plan for the socio-economic development of Atyrau region for 2021–2025]. (in Russian). <https://www.adilet.zan.kz/rus/docs/P2200000042> (in Russian)

He W., Shang J., Lu X., Fan C. (2013) Effects of sludge dredging on the prevention and control of algae-caused black bloom in Taihu Lake, China. *Journal of Environmental Sciences*, 25(3). — P. 430–440. [https://doi.org/10.1016/S1001-0742\(12\)60098-9](https://doi.org/10.1016/S1001-0742(12)60098-9) (in Eng.)

Kalmakhanova M. S., Diaz de Tuesta J. L., Malakar A., Gomes H. T., Snow D. D. (2023) Wastewater treatment in Central Asia: Treatment alternatives for safe water reuse. *Sustainability*, 15(20). — P. 14949. <https://doi.org/10.3390/su152014949> (in Eng.)

Kenessary D., Kenessary A., Kenessariyev U., Juszkiewicz K., Amrin M., Erzhanova A. (2017) Human health cost of hydrogen sulfide air pollution from an oil and gas field. *Annals of Agricultural and Environmental Medicine*, 24(2). — P. 213–216. <https://doi.org/10.26444/aaem/74562> (in Eng.)

Ministry of Healthcare of the Republic of Kazakhstan. (2022) [Prikaz ot 2 avgusta 2022 goda № KR DSM-70. “Ob utverzhdenii Gigiyenicheskikh normativov k atmosfernomu vozdukh v gorodskikh i selskikh naselennykh punktakh. na territoriyakh promyshlennykh organizatsiy” [Order No. KR DSM-70 of 2 August 2022 “On approval of Hygienic Standards for Ambient Air in Urban and Rural Settlements and on the Territories of Industrial Organizations”]. <https://zakon.uchet.kz/rus/docs/V2200029011?ysclid=mul21kl6fu456106553> (in Russian).

Mustafina A., Inkárova Z., Baimukasheva G., Jexenov M., Tukhfátov Z. (2025) Impact of oil and gas fields on atmospheric air and public health in Atyrau region (a case study of Zhylyoi district). *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences*, 4(472). — P. 260–278. <https://doi.org/10.32014/2025.2518-170X.543> (in Eng.)

Ragothaman A., Anderson W. A. (2017) Air quality impacts of petroleum refining and petrochemical industries. *Environments*, 4(3). — P. 66. <https://doi.org/10.3390/environments4030066> (in Eng.)

Reese B. K., Anderson M. A., Amrhein C. (2008) Hydrogen sulfide production and volatilization in a polymictic eutrophic saline lake, Salton Sea, California. *Science of the Total Environment*, 406(1–2). — P. 205–218. <https://doi.org/10.1016/j.scitotenv.2008.07.021> (in Eng.)

RSE Kazhydromet. (2026) Informatsionnyi byulleten o sostoyanii okruzhayushchei sredy Atyrauskoj oblasti [Information bulletin on the state of the environment in Atyrau region]. Ministry of Ecology and Natural Resources of the Republic of Kazakhstan. (in Russian). https://www.kazhydromet.kz/uploads/files_calendar/10438/file/69b805abdd433atyrau-russ-byulleten-za-fevral-2026g-2.pdf (in Russian)

Ryskalieva D., Yessenamanova M., Koroleva E. G., Yessenamanova Z., Tlepbergenova A., Amanzholykyzy S., Turekeldiyeva R. (2022) Monitoring study of the effect of Atyrau evaporation fields on the content of hydrogen sulfide in the air. *International Journal of Sustainable Development and Planning*, 17(6). — P. 1789–1796. <https://doi.org/10.18280/ijstdp.170613> (in Eng.)

Salih M. Q., Hamadamin R. R., & Hama J. R. (2023) Emission and exposure of hydrogen sulfide in the air from oil refinery: Spatiotemporal field monitoring. *International Journal of Environmental Science and Technology*, 20(5). — P. 4727–4736. <https://doi.org/10.1007/s13762-022-04309-2> (in Eng.)

Sanchez N. P., Saffari A., Barczyk S., Coleman B. K., Naufal Z., Rabideau C., Pacsi A. P. (2019) Results of three years of ambient air monitoring near a petroleum refinery in Richmond, California, USA. *Atmosphere*, 10(7). — P. 385. <https://doi.org/10.3390/atmos10070385> (in Eng.)

Ulman A., et al. (2026) Air pollution in the West Kazakhstan region: A multi-source analysis. *Atmospheric Research*. 330. 108560 <https://doi.org/10.1016/j.atmosres.2025.108560> (in Eng.)

Yessenamanova M., Yessenamanova Z., Tlepbergenova A., Batyrbayeva G. (2021) Analysis of the content of hydrogen sulfide in the air of the city of Atyrau. *International Journal of Sustainable Development and Planning*, 16(3). — P. 479–483. <https://doi.org/10.18280/ijstdp.160308> (in Eng.)

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