IRSTI 39.01.94 https://doi.org/10.26577/JGEM.2024.v72.i1.09

A.N. Mussagaliyeva*, M.A. Zhunussova, Z.M. Assipova, N.A. Kurbankozha, K.Z. Kosherbay

Al-Farabi Kazakh National University, Kazakhstan, Almaty
*e-mail: aizhan.mussagaliyeva@kaznu.edu.kz

ASSESSMENT OF TECHNOGENIC IMPACT ON THE ENVIRONMENT OF THE KARAGANDA REGION

The Karaganda Region, known for its extensive industrial activities, including mining, metallurgy, and energy production, faces significant environmental challenges. These industries, vital for the region's economic development, are also major sources of pollution, contributing to air, water, and soil contamination. The assessment of the technogenic impact is crucial for understanding the extent of environmental degradation, identifying the primary sources of pollution, and developing strategies to mitigate these effects.

The article presents an analysis of the technogenic impact on the environment of the Karaganda region. The study is based on the analysis of statistical data, the results of practical research and the application of modern methods.

The study identifies the anthropogenic challenges facing the Karaganda region, particularly heavy metal pollution from the mining and metallurgical industries, as well as contributions from the automotive sector and thermal power plants. It uses environmental performance data for linear scaling. As a result of the study, regions that made a significant contribution to environmental pollution were identified, a map of environmental emissions was created, and recommendations were proposed for improving the state of the natural environment of the Karaganda region. The presented analysis will allow us to better understand the nature of anthropogenic impact on the environment and develop recommendations for minimizing it to preserve environmental well-being.

Key words: technogenic impact, environmental management, emissions, Karaganda region, sustainable development.

А.Н. Мусагалиева*, М.А. Жунусова, Ж.М. Асипова, Н.Ә. Құрбанқожа, Қ.Ж. Көшербай

Әл-Фараби атындағы Қазақ ұлттық университеті, Казақстан, Алматы қ.
*e-mail: aizhan.mussagaliyeva@kaznu.edu.kz

Қарағанды облысының қоршаған ортасына техногендік әсерін бағалау

Тау-кен өнеркәсібі, металлургия және энергетика салаларын қоса алғанда, кең ауқымды өндірістік қызметімен танымал Қарағанды облысы күрделі экологиялық мәселелерге тап болып отыр. Аймақтың экономикалық дамуы үшін маңызды салалар ауаны, суды және топырақты ластауға ықпал ететін негізгі ластаушы көздер болып табылады. Қоршаған ортаға әсерді бағалау табиғаттың тозу дәрежесін түсіну, ластанудың негізгі көздерін анықтау және осы әсерлерді азайту стратегияларын әзірлеу үшін өте маңызды.

Мақалада Қарағанды облысының қоршаған ортаға техногендік әсерінің талдауы берілген. Зерттеу статистикалық мәліметтерді талдауға, тәжірибелік зерттеулердің нәтижелеріне және заманауи әдістерді қолдануға негізделген.

Зерттеу Қарағанды облысының алдында тұрған антропогендік әсерлердің, әсіресе тау-кен және металлургия өнеркәсібінің ауыр металдармен ластануын, сондай-ақ автомобиль секторының, және жылу электр станцияларының салымдарын анықтайды. Ол сызықтық масштабтау үшін қоршаған орта өнімділігі деректерін пайдаланады. Зерттеу нәтижесінде қоршаған ортаны ластауға елеулі үлес қосқан өңірлер анықталып, қоршаған ортаға шығарындылар картасы жасалып, Қарағанды облысының табиғи ортасының жағдайын жақсарту бойынша ұсыныстар берілді. Ұсынылған талдау қоршаған ортаға антропогендік әсердің табиғатын түсінуге және экологиялық әл-ауқатты сақтау үшін оны азайту бойынша ұсыныстар әзірлеуге мүмкіндік береді.

Түйін сөздер: техногенді әсер, қоршаған ортаны басқару, шығарындылар, Қарағанды облысы, тұрақты даму.

А.Н. Мусагалиева*, М.А. Жунусова, Ж.М. Асипова,
Н.А. Курбанкожа, К.Ж. Кошербай
Казахский национальный университет имени аль-Фараби, Казахстан, г. Алматы
*e-mail: aizhan.mussagaliyeva@kaznu.edu.kz

Оценка техногенного воздействия на окружающую среду Карагандинской области

Карагандинская область, известная своей обширной промышленной деятельностью, включая горнодобывающую, металлургическую и энергетическую промышленность, сталкивается с серьезными экологическими проблемами. Эти отрасли промышленности, жизненно важные для экономического развития региона, также являются основными источниками загрязнения, способствуя загрязнению воздуха, воды и почвы. Оценка техногенного воздействия имеет решающее значение для понимания масштабов деградации окружающей среды, выявления основных источников загрязнения и разработки стратегий по смягчению этих последствий.

В статье представлен анализ техногенного воздействия на окружающую среду Карагандинской области. Исследование основано на анализе статистических данных, результатах практических исследований и применении современных методов.

В исследовании обозначены проблемы техногенного воздействия, с которыми сталкивается Карагандинская область, в частности загрязнение тяжелыми металлами от горнодобывающей и металлургической промышленности, а также вклад автомобильного сектора и тепловых электростанций. В нем используются данные экологических показателей для линейного масштабирования. В результате исследования были выявлены регионы, вносящие значительный вклад в загрязнение окружающей среды, была создана карта выбросов в окружающую среду, а также были предложены рекомендации по улучшению состояния природной среды Карагандинской области. Представленный анализ позволит лучше понять природу антропогенного воздействия на окружающую среду и разработать рекомендации по его минимизации для сохранения экологического благополучия.

Ключевые слова: техногенное воздействие, природопользование, выбросы, Карагандинская область, устойчивое развитие.

Introduction

In the contemporary world, the issue of anthropogenic impacts on the environment is gaining increasing significance. The accelerated development of industry, intensification of agricultural production, growth of urban agglomerations, and an increase in transport flows lead to a significant deterioration of the ecological situation in many regions globally. These changes directly affect not only the state of natural resources but also human health, economic development, and the quality of life of populations.

Anthropogenic environmental impact encompasses a broad range of factors: from emissions of industrial enterprises and vehicular transport to the construction of large infrastructure projects and the operation of energy facilities. All these contribute to the pollution of the atmosphere, water resources, soil, as well as to the loss of biodiversity and climate change.

A range of anthropogenic activities, from industrial production to construction and energy facilities, have been found to significantly impact the environment. Ippolitova (Ippolitova, 2019) and Magomet (Magomet, 2015) both highlight the negative effects of industrial activities, with Ippolitova emphasizing the uneven distribution of industrial facilities and their impact on the living environment, and Magomet identifying soil and water pollution near industrial waste landfills. Akan (Akan, 2017: 1195) further underscores the environmental impact of the construction industry, particularly in developing countries, and the need for sustainable practices. Ansari (Ansari, 2014: 71) expands the discussion to include the contamination of coastal marine environments, emphasizing the cumulative and synergistic effects of various anthropogenic factors.

Recognizing the scale and consequences of anthropogenic environmental impacts requires a comprehensive approach to studying this issue. It is crucial not only to analyze the current state of the ecological environment but also to develop effective methods to minimize negative impacts, as well as strategies for adaptation to the changes that have already occurred.

The Karaganda region, is characterized by diverse natural conditions, including a complex relief and a high risk of wildfires (Kenetayeva, 2021, 2022). It is a significant industrial center, with a fo-

cus on mining and metallurgy (Kenetayeva, 2021). The region's geological structures, particularly the Karaganda synclinorium, have been extensively studied (Kenetayeva, 2022)

The research outlines the critical pollution challenges facing the Karaganda Region, notably heavy metal contamination from mining and smelting industries, alongside contributions from the automotive sector, waste disposal sites, and thermal power plants. It emphasizes the utilization data for linear scaling, providing a current snapshot of ecological data to normalize and compare various environmental indicators within that year. This approach highlights regions contributing significantly to pollution, pinpointing where targeted emission reduction and environmental management efforts are most needed.

Human activity leads to environmental transformations, frequently on a large scale. The negative consequences of anthropogenic actions influent on ecosystems, including health hazards and ecological threats (Chmielewski, 2018). Anthropogenic chemical contamination is one of the most evident signals of human influence on the environment. The large amounts of industrially produced pollutants that have been introduced, over decades, into air, soil and water have caused modifications to natural elemental cycling. Anthropogenic contamination usually leads to enrichment in many elements, particularly in industrial areas (Ma, Rong, 2021).

In today's market-driven economy, as industries continue to grow rapidly, the environmental impact of industrial activities and the efficient use of natural resources become crucial issues. With increasing environmental challenges and the depletion of natural resource reserves, there's a heightened focus on implementing effective environmental protection measures in industries affecting the environment.

Karaganda region is a major industrial center of Kazakhstan. Today, several hundred enterprises of many industries are concentrated in the region, which not only produce various products, but also intensively pollute the environment. The high concentration of environmentally dirty industrial production, the joint location of industrial enterprises and residential areas without taking into account environmental safety has led to the fact that the population of these areas lives in the zone of permanent action of these harmful industries and their waste. Air protection remains a serious problem. It has become somewhat cleaner in recent years. Of particular concern are the emissions of pollutants from vehicles. This is primarily due to the fact that the main highways pass through residential areas of the region's cities. Exhaust gases emit more than 200 types of harmful substances, some of which have toxic and carcinogenic properties. One of the factors that have a negative impact on the environmental situation of the region is the release of methane gas into the atmosphere. The main thing for the protection of atmospheric air was and still is the introduction of the latest technological processes, environmentally friendly and waste-free technologies and generally clean production, and not patching holes, as is done at many enterprises. A number of enterprises do not implement measures for the use of low-ash coals, which leads to increased ash emissions into the atmosphere. However, due to the large difference in cost, high-ash coals are still widely used, especially in thermal power plants. This is just one of the examples when the economy prevails over the environment and leads to the fact that the environmental well-being of the region and the health of the people later costs more than such an economy (Zhupysheva, 2020)

Materials and methods

The impact of technogenic factors on the environment of the Karaganda region is a significant concern, as highlighted by Alimbaev (Alimbaev, 2020) and Beisenova (Beisenova, 2020). The development of oil fields and the associated raw material management system have led to high technogenic loads, causing changes in soil properties, disruption of the hydrological regime, and reduction in animal populations (Alimbaev, 2020). This has resulted in a serious deterioration of natural resources and the environment in the region (Beisenova, 2020). Ibragimova and Podkovyrova (2020) highlight the importance of evaluating environmental risks thoroughly, particularly from industrial facilities and transportation, to promote sustainable development. Researchers have proposed various techniques for assessing the environmental impact of technology. Krupskaya (2019) and Abalakov (2018) both advocate using GIS (Geographic Information Systems) technologies. Krupskaya's focus is identifying pollution patterns and pollutant dispersion, while Abalakov uses mapping methods to analyze the impact of mining operations. Dewick (2004) examines the long-lasting environmental effects of widespread technology. Meanwhile, Porter (1998) assesses diverse techniques for predicting and evaluating the environmental implications of technological advancements and economic progress. These studies emphasized the significance of evaluating both

short-term and long-lasting effects of technology. To accurately comprehend the intricate impact of technology, it is necessary to employ various assessment techniques.

The Karagandy region struggles with severe pollution issues. Heavy metals from mining and smelting operations pose a serious threat (Ghazaryan, 2014). Cities like Karaganda suffer heavily, facing high levels of carbon monoxide, phenol, and formaldehyde (Tseshkovskaya, 2021). Additionally, coal mining in the Karaganda coal basin significantly contributes to air pollution, worsening the region's environmental problems (Zengina, 2013).

Linear scaling in ecology makes it possible to use and compare ecological data that uses different units or scales. It transforms data into a common format, making it easier to understand and analyze. This method is often used in preparing data for modeling, studying how different things affect the environment, and comparing sustainability measurements in different areas.

Matthias (2020) offers a thorough look at the different ways ecologists can scale their models. The research provides a comprehensive overview of the various scaling approaches used in ecological modeling. The content covers a range of techniques and methodologies that reserchers can employ to handle the complexities of modeling ecological systems at different scales.The authors classify scaling into pre-model scaling, in-model scaling, and post-model scaling, depending on when the scaling relative to the main modeling process occurs. General approaches, examples, and potential application problems for each category, highlighting that scaling issues might be more widespread than previously thought were discussed. These scaling challenges are matched with a range of solutions, which often need to be adapted and tailored to the specific scaling case.

The core principle of this method is to bring all values to a range between specified minimum and maximum values, often between 0 and 1. Comparing pollution levels in different locations by normalizing pollutant concentration values. Evaluating and comparing the influence on the environment of various projects or territories.

Modeling ecological processes using data brought to a common scale to increase the accuracy and comparability of results. The advantages of this method include its universality, as it is suitable for data of various natures and scales; simplicity of implementation, easily applied using standard data analysis tools; and improved comparability of data, facilitating the comparison and analysis of data obtained from different sources.

The objective of the scientific research is to conduct a comprehensive evaluation of the influence exerted by industrial activities and other forms of anthropogenic impact on the natural components and ecosystems within one of Kazakhstan's key industrial regions.

Initially, it is essential to analyze existing data and sources to identify the most significant factors of anthropogenic impact in the Karaganda Region using official statistic data of Bureau of National Statistics Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, 2013-2022 (Bulletin, 2013-2022). Subsequently, the research aims to assess the extent and specificity of the influence of industrial enterprises, transportation, agricultural activities, and other sources on the quality of air, water resources, soil, as well as on the state of biodiversity in the region. The study will create methods to monitor and assess how humans affect the environment. These methods will organize and analyze data to draw informed conclusions and recommendations. The ultimate goal is to create a plan to lessen the harmful effects of human activities on the environment and enhance ecosystems' resilience to human influence.

Results and discussion

The Karaganda region, a major industrial hub in Kazakhstan, is plagued by severe environmental issues caused by multiple pollution sources. The metallurgical industry emits harmful substances like sulfur dioxide, heavy metals, and other pollutants into the air and soil. Mining operations for coal, copper, and gold pollute the air, water, and soil due to activities like coal extraction, mine tailings, and quarrying. Additionally, coal-fired power plants contribute to air pollution by releasing carbon dioxide, sulfur and nitrogen oxides, ash, and slag. Transportation, especially in cities, significantly contributes to air pollution by releasing harmful substances like hydrocarbons and carbon dioxide. Agriculture emits pesticides, fertilizers, and livestock waste that pollute water and soil. Inadequate waste management systems contaminate water and soil, and burning waste releases pollutants into the air. To combat these problems, we need extensive solutions: updating industrial machinery, enhancing waste management, embracing eco-friendly technologies, and educating the public about the environment.

Assessing the anthropogenic impact on the environment of the Karaganda region, analyzing the distribution of stationary emission sources across different districts provides a crucial insight into the scope of the issue and helps in devising effective strategies for its mitigation. The Karaganda region as a whole represents 50% of the total number of stationary emission sources, highlighting the scale of industrial impact on the environment in this area.

The Karaganda city area emerges as the principal industrial hub of the Karaganda Region, hosting the majority of both mining and manufacturing enterprises (Figure 1). This indicates a high concentration of industrial potential and its corresponding technogenic impact on the environment within this zone. Districts such as the Balkhash city area and Temirtau city area are also significant for the region's economy but hold a smaller portion of the overall industrial structure of the Karaganda Region. The mining and quarrying industry encompasses a total of 407 enterprises. A significant proportion of these are located in the Karaganda city area, with 314 (77%) enterprises, representing a substantial share of the total mining industry in the region. Other districts such as Balkhash city area and Temirtau city area also contribute to the industry, albeit to a lesser extent. The manufacturing sector is represented by 2076 enterprises, with the majority also concentrated in the Karaganda city area (69 %). This highlights the urban agglomeration's industrial orientation. The Temirtau city area stands out with 326 enterprises, affirming its status as a crucial industrial center within the region.

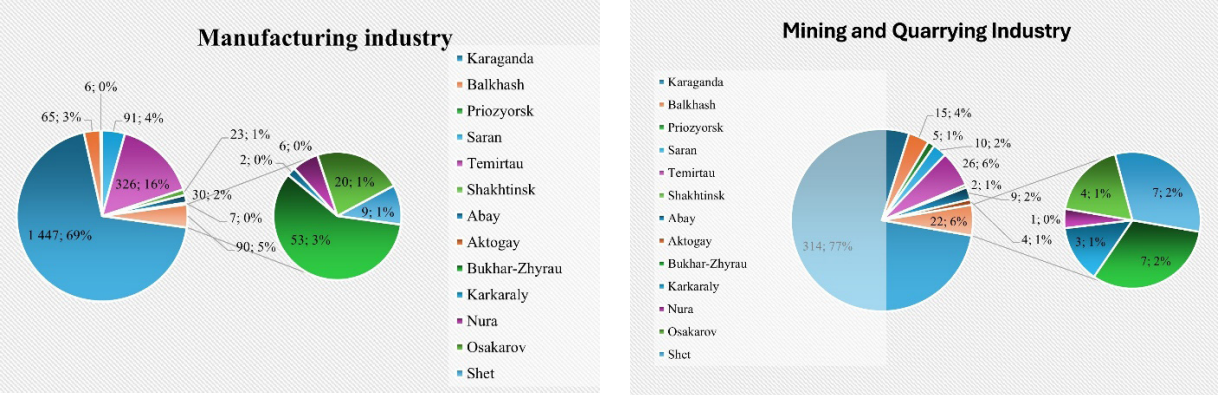

Figure 1 – Industrial enterprises of the Karaganda region, units, percent

Karaganda city area alone accounts for 28,78% of all stationary emission sources, highlighting the concentration of industrial activities in this urban agglomeration. This area also contributes 27,54% to the organized emissions and has 29,08% of its sources equipped with purification facilities, underlining the critical role it plays in the region's environmental dynamics.

Temirtau city area emerges as a notable contributor, especially in terms of sources equipped with purification facilities, representing 35,92% of the total. This shows a strong push to reduce pollution in this industrial hub. Other areas, like Balkhash city and Bukhar-Zhyrau district, also have a significant number of pollution sources and purification facilities. This highlights the need for focused efforts in these areas to minimize their environmental impact (Figure 2).

Between 2017 and 2022, the number of sources emitting pollutants in the Karaganda region underwent notable changes. Overall, a significant decline of 1024 sources was observed. Karaganda city had the highest reduction with 231 fewer sources. In contrast, Aktogay and Abay districts experienced substantial increases, with 234 and 184 new sources, respectively, marking the most significant growth in the region.

There was a significant decline in organized sources of air pollution, with 1857 fewer sources across the region. Karaganda saw the largest decrease with 541 fewer organized sources. Efforts to control emissions also improved. The region saw an increase of 83 facilities with purification systems, particularly in the Balhash area, which added 26 new installations.

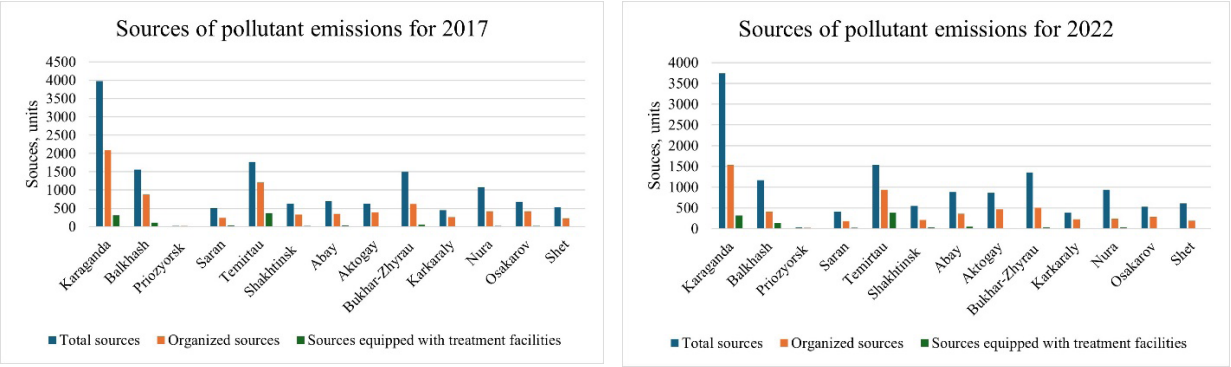

Figure 2 – Sources of pollutant emissions of the Karaganda region for 2017-2022, units

The Karaganda region has seen changes in its industries and environment. This is due to new technology for controlling emissions, as well as changes in government policies and the economy that affect industrial activities. The increase in purification equipment is a good sign for reducing environmental pollution. However, the decrease in sources of emissions that are managed could also be a sign of economic changes and restructuring in the area.

Karaganda's heavy industries, including mining, metalworking, and energy production, create significant environmental concerns. While these industries boost the region's economy, they also pollute the air, water, and soil. Among these pollutants, airborne emissions are particularly alarming due to their impact on air quality and potential global consequences. Compared to other environmental challenges like industrial water runoff, excessive soil use, and waste disposal, air pollution has far-reaching effects, affecting human health and ecosystems. Air pollution extends beyond local areas and impacts both cities and countryside. It contributes to wider environmental concerns, unlike water and soil pollution, which are often confined to specific locations.

Major sources of pollution in the region involve industries like "Kazakhmys Corporation" LLP, "ArcelorMittal Temirtau" JSC, and "TEMK" HMZ JSC. Other contributors include vehicle traffic, trash disposal sites, power plants, manufacturing facilities, railroads, and car transportation firms. These sources discharge various toxins into the air, water, and soil, harming the environment and posing health risks to the population. The presence of major industrial companies highlights the significant environmental impact of mining and metallurgy. These sectors rely heavily on natural resources and release pollutants like heavy metals, sulfur dioxide, nitrogen oxides, and particulate matter. Similarly, TEMK HMZ JSC, representing the heavy machinery industry, also contributes to air and soil pollution through its activities. Transportation, particularly through automobiles, releases air pollutants like hydrocarbons, nitrogen oxides, carbon monoxide, and particles, harming air quality, especially in cities. Improperly managed landfills for household waste contaminate soil and water, while also potentially releasing methane, a strong greenhouse gas. Thermal power plants, essential for energy production, contribute to air pollution and climate change by emitting sulfur oxides, nitrogen oxides, particles, and carbon dioxide. Foundry and mechanical plants, along with train and car transport systems, further add to the environmental impact through their emissions and waste generation.

To tackle pollution from these sources, we need to use cleaner production methods, make tougher environmental rules, improve waste management, and raise public and business awareness of environmental sustainability. It's important to reduce the environmental impact of these activities to protect nature, improve people's health, and keep the area growing in a sustainable way.

Based on data from Kazhydromet, the primary contaminants in Karaganda's water bodies include ammonium ions, several minerals (manganese, calcium, magnesium), chlorides, and total dissolved solids. These pollutants primarily result from wastewater discharges that exceed established quality standards. During 2023, the following rivers in the region experienced significant pollution levels: Nura River – 5 incidents of high pollution due to elevated total iron levels; Sokyr River – 5 incidents of high pollution due to high ammonium ion and chloride levels; Sherubainura River – 11

incidents of high pollution due to elevated levels of chlorides, ammonium ion, total phosphorus, and total iron; Kara Kengir River – 37 incidents of high pollution due to elevated levels of ammonium ion, total phosphorus, total iron, BOD5, chlorides, and dissolved oxygen, and 3 incidents of extremely high pollution due to severely depleted dissolved oxygen levels (Information bulletin, 2023).

The Karaganda area faces significant environmental concerns, especially regarding water pollution. Industrial corporations and transportation play a substantial role in this pollution, necessitating strict regulations, cleaner manufacturing techniques, and comprehensive waste and wastewater management. Violations in water quality, such as high levels of ammonium ions, chlorides, and dissolved solids, emphasize the urgent need to protect water resources and maintain the health of aquatic ecosystems in the region.

From 2013 to 2022, pollution emissions in the Karaganda region varied (Figure 3). The largest contribution to the pollution of the region comes from the city of Temirtau (48%), Balkhash (16%) and Abay district (13%), Karaganda (9%). In 2013, 2017, and 2022, emissions varied across different areas, suggesting both challenges and progress in controlling industrial pollution. Notably, Karaganda City Area saw a significant decline, from 58 849,986 in 2013 to 45 954,231 in 2022, showing effective environmental measures. This 22% reduction demonstrates the region's efforts in minimizing its environmental impact. On the other hand, the Aktogay District saw a massive rise in emissions, from 970,497 in 2013 to 4 501,397 in 2022. This significant increase of more than 363% indicates that industrial activities have expanded without corresponding improvements in emission control mechanisms (Bulletin, 2013-2022).

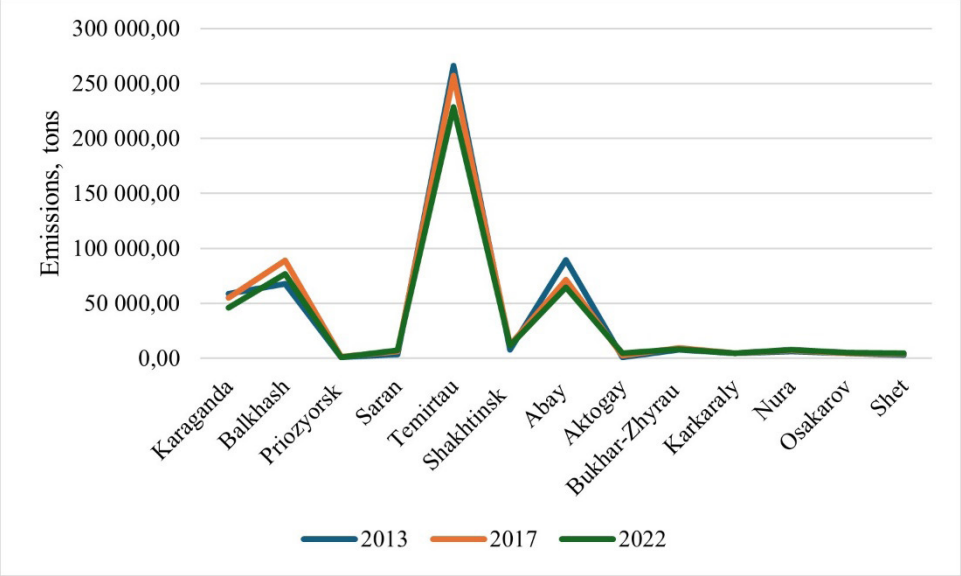

Figure 3 – Pollutant emissions of the Karaganda region for 2013-2022

Both Balhash and Priozersk experienced changes in emissions. Balhash saw an initial rise from 67 578,55 in 2013 to 88 774,968 in 2017, but later decreased to 76 424,753 in 2022. This resulted in a net increase of about 13% over nine years. The pattern suggests a period of higher emissions followed by successful efforts to reduce pollution. On the other hand, Priozersk witnessed an increase from 942,138 in 2013 to 1 235,629 in 2017, followed by a drop to 719,724 in 2022. This represents a net decrease of roughly 24%, indicating varying effectiveness of pollution control measures over time. Unlike other regions, Saran City Area has seen a steady increase in emissions from 3 361,999 tons in 2013 to 7 067,185 tons in 2022. This 110% jump has raised environmental concerns. On the other hand, Shet District and Karkaralinsk District have experienced lower emission increases, suggesting reduced industrial activities or stronger pollution controls.

Since no major changes in emissions occurred during the research period, it is appropriate to use the 2022 data for linear scaling (Figure 4). This method provides an overview of ecological data at a specific time, enabling comparisons and normalization of environmental indicators within that year. By applying linear scaling to the 2022 data, each value is adjusted to a common scale, typically ranging from 0 to 1. This involves finding the minimum value in the dataset and subtracting it from each data point. The resulting value is then divided by the dataset's range, which is the difference between the maximum and minimum observed values. This method standardizes raw data by converting it to a scale with values ranging from 0 (lowest value) to 1 (highest value).

Using this method for 2022 data makes it easier to compare different measurements or areas. This helps us see environmental conditions and how well different places or industries are doing. It also helps us find outliers or trends, which helps us see how current environmental policies and strategies are working. By focusing on one year's data and scaling it linearly, we can learn a lot about the environment, which can help us make better decisions and create better policies in the future.

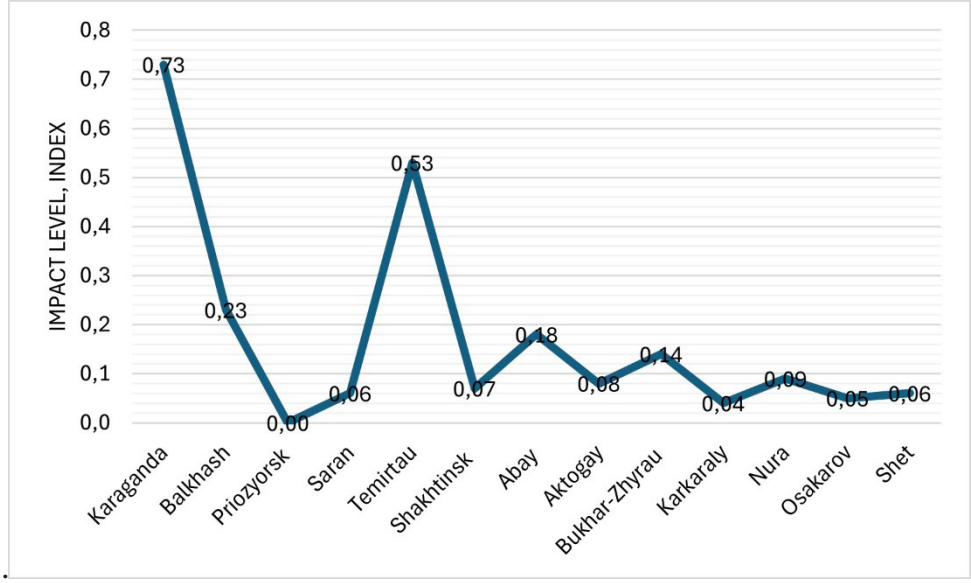

Figure 4 – Level of environmental impact in the Karaganda region

Environmental impacts were analyzed using a scale of 0 (least impact) to 1 (highest impact) across different areas in the Karaganda region. Karaganda city has the most significant impact at 0.73, likely due to industrial activity or mining. Priozersk has the lowest impact at 0.00, indicating minimal environmental effects as there are no major pollution sources. Saran and Shakhtinsk have low impacts at 0.06 and 0.07, respectively, suggesting limited industrial activities in those areas.

Temirtau has a significant environmental impact score of 0.53, likely due to heavy industries common in the region. In contrast, Balkhash, Abay, Aktogay, Bukhar-Zhyrau, Karkaraly, Nura, Osakarov, and Shet have lower scores ranging from 0.004 to 0.018, suggesting lower to moderate environmental impacts. These differences may be influenced by varying industrial activities, farming practices, or conservation measures.

The total amount of emissions from different sources, rather than the number of sources or companies involved, determines the environmental impact. To highlight this, a map of pollutant emissions in the Karaganda region was developed. It identifies areas contributing significantly to the region's overall pollution levels (Figure 5).

Environmental zoning based on emissions consists of five impact levels: very high, high, average, low, and very low. Temirtau has the highest emissions, classified as very high impact. Karaganda, Balkhash, and Abai district have high emissions. Saran, Shakhtinsk, Bukhar-Zhyrau, and Nura have average emissions. Aktogay, Karkaraly,

Osakarov, and Shet have low emissions. Priozersk has very low emissions.

By dividing the Karaganda region into areas with different environmental impacts, we can see where improvements are most needed. Temirtau has the worst environmental impact, showing the urgent need for stricter pollution controls and cleaner industrial practices. The areas with significant or moderate impacts also need attention to reduce emissions, but their specific needs may vary depending on the pollution sources and amounts. Conversely, areas considered low or very low impact experience less environmental stress, likely due to reduced industrial activity. This zoning system is crucial for guiding environmental policies and actions, fostering a comprehensive strategy to enhance air quality and minimize the environmental impact in the Karaganda region as a whole.

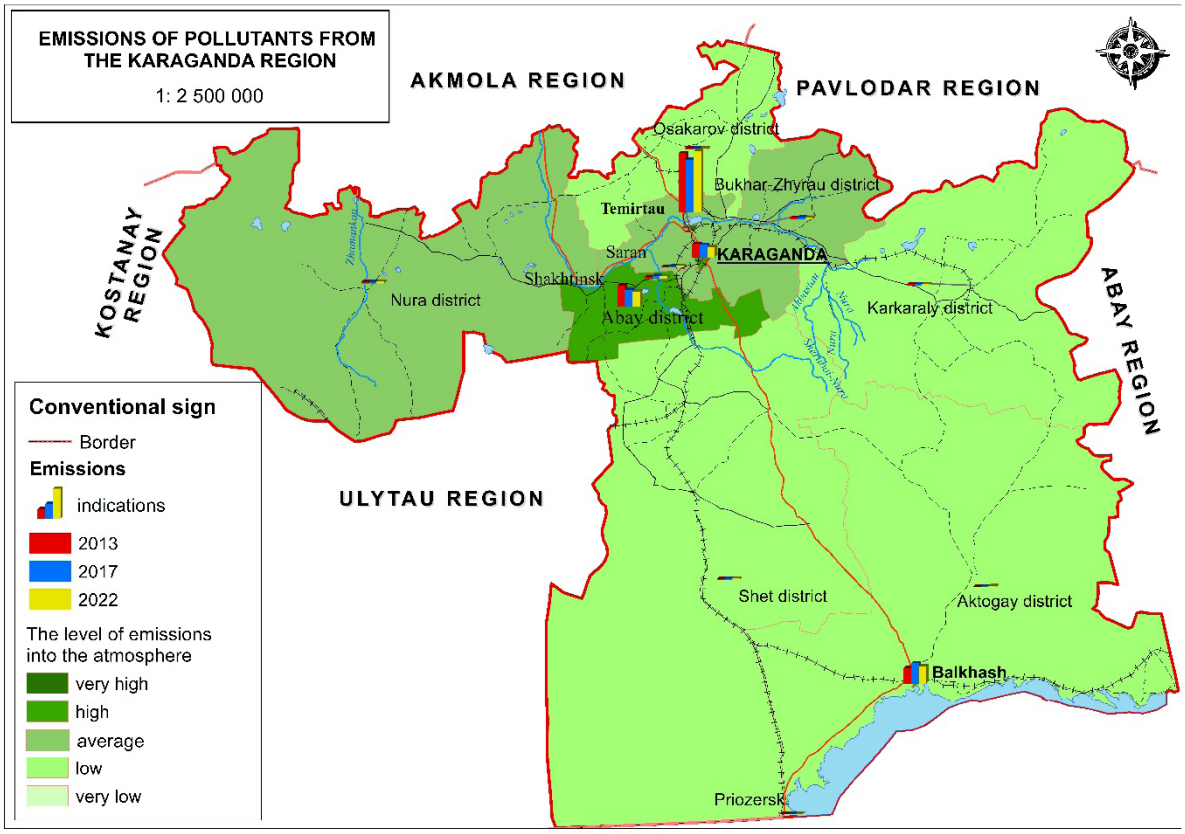

Figure 5 – Emissions of pollutants of the Karaganda region

Developing a pollution emission map for Karaganda is crucial for comprehending and managing the region's ecological well-being. This map identifies areas that contribute the most to pollution and serves as a basis for designing precise strategies to lessen environmental impact. By concentrating on the overall amount of emissions rather than the number of sources or businesses, resources and efforts for environmental protection can be distributed more effectively.

Developing an emission map for Karaganda is essential for understanding and addressing its environmental concerns. By identifying areas with the highest pollution impact, the map guides targeted efforts to reduce harm to the environment. This map considers the combined impact of pollution sources, not just their number or business activity, allowing for more efficient allocation of resources for conservation. The map's ability to locate areas with increased pollution provides valuable information for various parties involved in environmental protection. This policy framework grants local and regional authorities the authority to: – prioritize environmental policies, –

implement measures to reduce emissions, – enable industries to improve their processes and adopt technologies to reduce their environmental impact, and – raise awareness among citizens and non-governmental organizations about environmental issues, encouraging their involvement in protecting the environment. Creating and analyzing a comprehensive map of pollution sources empowers a holistic approach to tackling the problem in the Karaganda region. It helps identify critical hotspots, develop targeted emission reduction programs, and raise public awareness about environmental issues. This comprehensive strategy, guided by the map's diagnostic and strategic insights, enables both assessment and improvement of ecological conditions, leading to better environmental management and sustainable development in the region.

Table 1 – SWOT analysis of the state of the environment in the Karaganda region

Positive Factors	Negative factors
Strengths (S)	Weaknesses (W)
• Karaganda possesses abundant natural assets, such as vast forests, water sources, and varied plant and animal life, which are critical for preserving the environmental equilibrium. • The region's industrial infrastructure and expertise in implementing technological advancements offer opportunities to advance and implement environmentally responsible techniques. • Leveraging contemporary monitoring techniques and GIS technology allows for a more thorough understanding of pollutant distribution and environmental health assessments.	• Industrial operations, particularly mining and metallurgy, have a substantial negative impact on the environment. • Current water treatment systems are inefficient, and advanced technologies are not widely used. • Scarcity of funding for environmental protection and modern purification systems hinders efforts to enhance the environmental conditions.
Potential Opportunities (O)	Current Threats (T)
• Employing advanced technologies and methods to decrease pollution. • Creating and enacting sustainable development plans, including educating the public about the environment and involving them in decision-making. • Utilizing the region's environmental resources for ecotourism can promote both environmental protection and economic growth. • Teaming up with international organizations and countries to share environmental innovations and technologies, which can contribute to improving the region's environmental conditions.	• The region faces challenges in balancing economic growth with environmental well-being. • Industrial activities, particularly coal mining and metal production, contribute significantly to the region's economy but also pose threats to the environment. • Climate change threatens to worsen the environmental situation, potentially reducing biodiversity and lowering the quality of life for residents.

To improve environmental conditions and support sustainable growth in the Karaganda Region the following recommendations are proposed:

- Promoting cleaner production practices by urging industrial companies, mainly in mining and metallurgy, to adopt innovative methods that reduce pollution.

- Improving environmental regulations by strictly enforcing existing rules and standards, ensuring compliance with water and air quality guidelines for industrial operations.

- Enhance monitoring and reporting through widespread environmental monitoring, using GIS technology to track pollution sources and levels precisely.

- Promote open reporting by enterprises on their emissions and waste disposal practices.

- Invest in modern waste treatment and recycling facilities to handle industrial and municipal waste better, minimizing soil and water contamination.

- Raise public awareness about environmental issues and foster community participation in environmental protection and sustainability efforts.

- Support research and development to advance environmental technologies and solutions, fostering innovation for sustainable practices.

Conclusion

To effectively tackle the environmental issues in Karaganda, it's crucial to adopt a holistic and visionary approach that harmonizes economic development with environmental preservation. The research indicates a pressing need for immediate actions to mitigate pollution and long-term strategies to ensure the region's ecological and economic health. An integrated environmental strategy is crucial, encompassing pollution control, conservation of ecosystems, and sustainable resource management, underpinned by thorough data analysis to inform policymaking. Achieving sustainability in the Karaganda Region calls for a collaborative effort among all stakeholders, including governmental bodies, industry, non-governmental organizations, and local communities, with a unified commitment to environmental stewardship.

Leveraging innovation and advanced technology is key to overcoming the region's ecological challenges. This includes adopting cleaner production methods, waste management solutions, and exploring renewable energy sources to lessen reliance on fossil fuels. Additionally, capacity building and education are vital for empowering local authorities, businesses, and communities with the knowledge and skills for sustainable practices. The region must also develop resilience strategies against climate change, protecting ecosystems and communities from its impacts through water conservation, land restoration, and biodiversity protection.

By incorporating these broader perspectives, the region can embark on a path toward not just addressing its immediate environmental concerns but also securing a sustainable and thriving future. This journey toward ecological sustainability is complex, demanding collective efforts, innovation, and a strategic vision to harmonize industrial development with environmental preservation, ensuring a prosperous future for the Karaganda Region and its inhabitants.

References

Abalakov, A. D. and N. B. Bazarova. "Assessment of the technogenic impact of the mining industry on the environment of the economic corridors "China – Mongolia – Russia" of the territory of Mongolia and the Baikal region." IOP Conference Series: Earth and Environmental Science 190 (2018): n. pag.

Akan, Mahmure Övül Arioglu, Dileep G. Dhavale and Joseph Sarkis. "Greenhouse gas emissions in the construction industry: An analysis and evaluation of a concrete supply chain." Journal of Cleaner Production 167 (2017): 1195-1207.

Alimbaev, Turgai, Zhanna Sabitbekovna Mazhitova, Bibizhamal Omarova, Kuralay Yermagambetova, Karlygash Atanakova and Aiman Zhumanova. "Ecology of the Western region in Kazakhstan: state and main directions of improvement." E3S Web of Conferences (2020): n. pag.

Ansari, Zakir Ali and S. G. Prabhu Matondkar. "Anthropogenic activities including pollution and contamination of coastal marine environment." Journal of Ecophysiology and Occupational Health 14 (2014): 71-78.

Beisenova, Raikhan, K. M. Akpambetova and Buren Scharaw. "Assessment of ecological and economic balance of the territory of the Karaganda region." (2020).

Bulletin on the state of atmospheric air protection in the Karaganda region. Bureau of National Statistics Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, 2013-2022

Chmielewski Jarosław, KusztalPiotr and Żeber-DzikowskaIlona. "Anthropogenic impact on the environment (case study)" Environmental Protection and Natural Resources 29, no.1 (2018): 30-37.

Dewick, Paul, Ken Green and Marcela Miozzo. "Technological change, industry structure and the environment." Futures 36 (2004): 267-293

Fritsch M, Lischke H, Meyer KM. Scaling methods in ecological modelling. Methods Ecol Evol. 2020;11:1368–1378.

Ibragimova, R. Sh. and Sokhiba Pirnazarova. "Environmental change as a result of technogenic factors (in Samarkand region)." (2020).

Information bulletin on the state of the environment in the Karaganda region. Issue No. 18. 2023 RSE Kazhydromet.

Ippolitova, Nina A.. "Anthropogenic impact of industrial production on the environment (on the example of the Siberian region)." IOP Conference Series: Earth and Environmental Science 381 (2019): n. pag.

Kenetayeva, A A, Sh E Usupayev, A Zh Akhmetova, A. S. Kusenova, G.S. Shaikhova and Zh. K. Bogzhanova. "Characteristics of the natural conditions of the Karaganda region." Journal of Physics: Conference Series 1889 (2021): n. pag.

Kenetayeva, A A, Sh E Usupayev, G.S. Shaikhova, A. K. Salkeyeva, A Zh Akhmetova and L. F Mullagaliyeva. "Natural conditions of the Karaganda region." IOP Conference Series: Earth and Environmental Science 981 (2022): n. pag

Krupskaya, L. T., L. I. Chekmareva and D.A. Golubev. "Assessment of Technogenic System Impact on Ecosphere Using GIS-Technologies (on the Example of Dalpolimetall Mining Enterprise)." IOP Conference Series: Earth and Environmental Science 272 (2019): n. pag.

Ma, Rong, Lei Li and Bing-Chang Zhang. "Impact assessment of anthropogenic activities on the ecological systems in the Xiongan New Area in the North China Plain." Integrated Environmental Assessment and Management 17 (2021): n. pag.

Magomet, R. D. and N. A. Mironenkova. “The Impact of Anthropogenic Activities on The Indicators of Environmental Pollution.” (2015).

Podkovyrova, Marina Anatolyevna, Anatoly Oleynik and Natalia Tirskikh. “Optimization of Natural and Economic Systems within the Land and Property Complex in the City of Kurgan in Accordance with the Study of Environmental Risks Using Topic Mapping Technologies.” (2020).

Porter, Alan L. and John J. Fittipaldi. “Environmental Methods Review: Retooling Impact Assessment for the New Century.” (1998).

Zhupyseva, S.B. Makysh. “Assessment of the ecological state of the region from technogenic impact on the environment (on the example of the Karaganda region)”. News of the National Academy of Sciences of the Republic of Kazakhstan. Series of social and human sciences. Volume 4, No. 332 (2020), 182 – 189

Information about authors:

Mussagaliyeva Aizhan (corresponding author) – PhD, Senior Lecturer of the Department of Geography, Land Management and Cadastre of Al-Farabi Kazakh National University (Almaty, Kazakhstan, e-mail: aizhan.mussagaliyeva@kaznu.edu.kz);

Zhunussova Makpal – doctoral student of the Department of Geography, Land Management and Cadastre of Al-Farabi Kazakh National University (Almaty, Kazakhstan, e-mail: zhunusenko_89@mail.ru);

Assipova Zhanna – PhD, Associate Professor of the Department of Department of Recreation Geography and Tourism of Al-Farabi Kazakh National University (Almaty, Kazakhstan, e-mail: assipova.zhanna@gmail.com);

Kurbankozha Nurdaulet – master student of the Department of Geography, Land Management and Cadastre of Al-Farabi Kazakh National University (Almaty, Kazakhstan, e-mail: nurdauletkurbankozha@mail.ru);

Kosherbay Kuanysh – Lecturer of the Department of Geography, Land Management and Cadastre of Al-Farabi Kazakh National University (Almaty, Kazakhstan, e-mail: kosherbay822@mail.ru).

Авторлар туралы мәлімет:

Мусагалиева Айжан Ниазбековна (корреспондент автор) – PhD, Әл-Фараби атындағы Қазақ ұлттық университеті, география, жерге орналастыру және кадастр кафедрасының аға оқытушысы (Алматы қ., Казақстан, эл. почта: aizhan.mussagaliyeva@kaznu.edu.kz);

Жунусова Макпал Асылхановна – Әл-Фараби атындағы Қазақ ұлттық университеті, география, жерге орналастыру және кадастр кафедрасының докторанты (Алматы қ., Казақстан, эл. почта: zhunusenko_89@mail.ru);

Асипова Жанна Медеуовна – PhD, Әл-Фараби атындағы Қазақ ұлттық университеті, рекреациялық география және туризм кафедрасының доценті (Алматы қ., Казақстан, эл. почта: assipova.zhanna@gmail.com);

Құрбанқожа Нұрдәулет Әділұлы – Әл-Фараби атындағы Қазақ ұлттық университеті, география, жерге орналастыру және кадастр кафедрасының магистранты (Алматы қ., Казақстан, эл. почта: nurdauletkurbankozha@mail.ru);

Көшербай Қуаныш Жомартұлы – Әл-Фараби атындағы Қазақ ұлттық университеті, география, жерге орналастыру және кадастр кафедрасының оқытушысы (Алматы қ., Казақстан, эл. почта: kosherbay822@mail.ru).

Previously sent: November 10, 2022
Re-registered: December 11, 2023
Accepted: February 5, 2024