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ECOLOGICAL-GEOGRAPHICAL ISSUES OF URBAN SYSTEM DEVELOPMENT IN ZHAMBYL REGION

This article provides a comprehensive analysis of the ecological and geographical challenges faced by urban systems in the Zhambyl region of Kazakhstan, focusing on environmental issues such as air pollution, water contamination, and the degradation of natural ecosystems. The rapid pace of urbanization and industrialization in the region has led to significant changes in the ecological balance, with cities like Taraz and the Zualinsky district being major contributors to pollutant emissions. The study highlights the impact of these environmental problems on public health, biodiversity, and regional climate change.

Using data from official reports, GIS technologies, and remote sensing, the article examines the distribution of pollutant emissions and identifies the key sources of pollution across various districts in the region. The results show that major industrial activities and high population density contribute to high levels of atmospheric pollution, while some districts, like Merken and Talas, have lower emission volumes due to less industrial development.

The study suggests that addressing these challenges requires a multi-faceted approach, including the implementation of stricter environmental regulations, the adoption of eco-friendly technologies, improved waste management systems, and the promotion of sustainable resource management. The article emphasizes the importance of public engagement and environmental education in fostering a more sustainable urban future. By analyzing the current ecological situation, this study offers valuable insights for policymakers and local authorities to develop strategies that balance urban development with environmental protection and public health in the Zhambyl region.

Key words: environmental-geographical problems, urban systems, environmental culture, atmospheric air pollution, deterioration of the environmental situation.

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Жамбыл облысының урбожүйелерін дамытудың экологиялық-географиялық мәселелері

Бұл мақалада ауаның ластануы, судың ластануы және табиғи экожүйелердің деградациясы сияқты экологиялық мәселелерге назар аудара отырып, Қазақстанның Жамбыл облысындағы қалалық жүйелердің алдында тұрған экологиялық-географиялық мәселелерге жан-жақты талдау жасалған. Аймақтағы урбанизация мен индустрияландырудың қарқынды қарқыны Экологиялық тепе-теңдіктің айтарлықтай өзгеруіне әкелді, Тараз және Зуалы аудандары сияқты қалалар ластаушы заттар шығарындыларының негізгі көзі болып табылады. Зерттеу осы экологиялық проблемалардың қоғамдық денсаулыққа, биоәртүрлілікке және аймақтық климаттың өзгеруіне әсерін көрсетеді.

Ресми есептердің, ГАЖ технологияларының және қашықтықтан зондтаудың деректерін пайдалана отырып, мақалада ластаушы заттар шығарындыларының таралуы зерттеліп, аймақтың әртүрлі аудандарында ластанудың негізгі көздері анықталған. Нәтижелер негізгі өнеркәсіптік қызмет пен халықтың жоғары тығыздығы атмосфераның ластануының жоғары деңгейіне ықпал ететінін көрсетеді, Ал Меркен және Талас сияқты кейбір аудандарда өнеркәсіптік дамудың төмендеуіне байланысты шығарындылар көлемі төмен.

Зерттеу көрсеткендей, бұл мәселелерді шешу қатаң экологиялық нормаларды енгізуді, экологиялық таза технологияларды енгізуді, қалдықтарды басқарудың жетілдірілген жүйелерін және ресурстарды тұрақты басқаруды ілгерілетуді қоса алғанда, көп қырлы тәсілді қажет етеді. Мақалада қаланың тұрақты болашағын қамтамасыз етуде жұртшылықты тарту мен экологиялық білім берудің маңыздылығы атап өтілген. Ағымдағы экологиялық жағдайды талдай отырып, бұл зерттеу саясаткерлер мен жергілікті өзін-өзі басқару органдарына Қала құрылысын Қоршаған ортаны қорғаумен және Жамбыл облысының қоғамдық денсаулығымен теңестіретін стратегияларды әзірлеу бойынша құнды ақпарат береді.

Түйін сөздер: экологиялық-географиялық проблемалар, урбожүйелер, экологиялық мәдениет, атмосфералық ауаның ластануы, экологиялық жағдайдың нашарлауы.

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Эколого-географические проблемы развития урбосистем Жамбылской области

В этой статье представлен всесторонний анализ экологических и географических проблем, с которыми сталкиваются городские системы в Жамбылской области Казахстана, с акцентом на такие экологические проблемы, как загрязнение воздуха, воды и деградация природных экосистем. Быстрые темпы урбанизации и индустриализации в регионе привели к значительным изменениям в экологическом балансе, при этом такие города, как Тараз и Зуалинский район, являются основными источниками выбросов загрязняющих веществ. В исследовании подчеркивается влияние этих экологических проблем на здоровье населения, биоразнообразие и изменение климата в регионе.

Используя данные официальных отчетов, ГИС-технологий и дистанционного зондирования, в статье рассматривается распределение выбросов загрязняющих веществ и определяются ключевые источники загрязнения в различных районах региона. Результаты показывают, что крупная промышленная деятельность и высокая плотность населения способствуют высокому уровню загрязнения атмосферы, в то время как в некоторых районах, таких как Меркен и Талас, объемы выбросов ниже из-за меньшего промышленного развития.

Исследование показывает, что решение этих проблем требует многоаспектного подхода, включая введение более строгих экологических норм, внедрение экологически чистых технологий, совершенствование систем обращения с отходами и содействие устойчивому управлению ресурсами. В статье подчеркивается важность привлечения общественности и экологического просвещения для создания более устойчивого городского будущего. Анализируя текущую экологическую ситуацию, это исследование дает ценную информацию политикам и местным органам власти для разработки стратегий, которые обеспечивают баланс между городским развитием, охраной окружающей среды и общественным здравоохранением в Жамбылской области.

Ключевы слова: эколого-географические проблемы, урбосистем, экологической культуры, загрязнение атмосферного воздуха, ухудшения экологической обстановки.

Introduction

Currently, global urbanization trends offer various development models, but their main goal is to create a comfortable and safe environment for city residents. Most cities in Kazakhstan are small in scale and face several pressing problems, such as limited infrastructure, inadequate public services, economic challenges resulting in unemployment, environmental problems, and housing shortages. (Kaimuldinova K. et al., 2024) The Sustainable Development Goals (SDGs) adopted by the UN are the basis for ensuring sustainable development at the global level. The 11th SDG, “Making cities open, safe and sustainable”, is closely linked to other goals, since cities are considered the main form of spatial organization of human society (UN DESA, 2015). The International ICLEI (Local Authorities for Sustainable Development) asserts that sustainable cities create an ecologically, socially and economically healthy and sustainable living environment for the current population and do so without compromising the ability of future generations to experience the same. The sustainability of cities is determined by various parameters, and its assessment system includes quantitative, qualitative, and descriptive criteria related to many areas.

A sustainable city is a socially, ecologically, and economically harmonious and stable system, the harmonious development of which is usually considered to be a balancing of this fundamental triple dimension of sustainability. A model for assessing sustainable urban development was proposed by researchers based on Australian studies, highlighting that the three-pronged approach to sustainability oversimplifies a complex issue. The model places particular emphasis on environmental indicators to ensure usability, accessibility, equity, and resource conservation. (Davidson K. et al, 2012). Building upon this, (Ding X. et al, 2015) introduced an expanded model for assessing the sustainability of cities, proposing the inclusion of spatial, chronological, and logical dimensions in addition to the traditional three pillars. Their approach, known as the Trinity of Cities' Sustainability from Spatial, Logical, and Time Dimensions (TCS-SLTD), provides a more comprehensive method of evaluating urban sustainability, especially in developing countries, where urban challenges differ significantly. Meanwhile, (Michalina D. et al, 2021) conducted an in-depth analysis of urban sustainability indicator frameworks (USIF) in global and European contexts, categorizing and classifying indicators based on aspects of sustainability. Their findings revealed that, in developed countries, environmental indicators are prioritized, while in developing countries, socio-economic indicators take precedence. This suggests that sustainability assessments must be tailored to the specific contexts of different regions, incorporating indicators that reflect local priorities and challenges. The effort towards sustainable cities needs to pay more attention to social and environmental issues, and social and environmental security should become the main focus of urban development (Niemets K. et al, 2021).

For a long time, empirical observation of the dynamics of urban ecosystems has been dominant, and gradually an adaptive approach to these changes, for management purposes, has become important. Dynamic relations between humanity and nature form socio-ecological systems (SES); currently, the concept of SES is based on the study of the interrelationships of social and environmental changes, as well as their impact on the achievement of sustainable development goals. Of course, many of these connections may be less obvious in big cities than in small settlements. However, multilevel, complex socio-ecological systems provide residents of every city with food, water, energy, and recreation services. When solving the tasks associated with the sustainable development of the city, not only positive changes in the socio-economic situation of the population are taken into account, but also their emotional connections with the environment, that is, values and memories associated with a certain natural environment. From this point of view, the collective values of a society and the recognition of oneself as a part of nature are the first steps in planning and implementing sustainable development solutions (Fuller J.L. et al, 2023). The territory of Kazakhstan has a unique set of landscape complexes: from deserts to highlands and ecosystems of the inland seas. In the context of the increasing pace of economic development of the country and the increased use of natural resources, the issue of preserving the biological diversity of ecological systems, unique natural complexes, objects of the nature reserve fund, cultural and natural heritage of the Republic of Kazakhstan is becoming relevant-one of the important tasks of the state at the present stage (Salikhov T. et al., 2023).

Ecological-geographical issues associated with the development of urban systems represent a pressing concern in contemporary society. Zhambyl region, located in the central part of Kazakhstan, is a region where these issues are particularly acute. The rapid process of urbanization, accompanied by intensive industrial and agricultural development, leads to significant changes in the region's ecological situation (Humanitarian portal: research and forecasts, 2024).

The aim of this article is to conduct a comprehensive analysis of the ecological-geographical problems facing the urban systems of Zhambyl region and to identify ways to address them.

Within the scope of this research, the main aspects of urbanization's impact on the region's natural environment will be examined, including degradation of natural ecosystems, pollution of atmospheric air and water resources, as well as threats associated with climate change. Additionally, the influence of environmental problems on public health and regional biodiversity will be analyzed.

Furthermore, concrete strategies and measures aimed at improving the ecological situation in urbanized areas of Zhambyl region and ensuring their sustainable development in the future will be proposed.

Rapid urbanization and accelerating socio-economic development have generated global problems from climate change and its environmental impacts to incipient crises in food, energy and water availability, public health, financial markets and the

global economy. Urbanization is a relatively new global issue (Bettencourt L., West G., 2010). Urbanization is one of the most significant processes in the world's modern development. With each passing year, more people move from rural to urban areas in search of employment, better education, and quality of life. This process leads to a significant increase in urban populations and expansion of urban areas. However, urbanization also has a profound impact on the environment and ecological conditions of regions (Pouland R.H., 2001).

Urbanization is a process that deeply affects the environmental conditions of regions in the Commonwealth of Independent States (CIS). In this chapter, we will examine how urbanization in various CIS countries influences the environmental situation and what problems it creates.

In CIS countries such as Russia, Ukraine, Kazakhstan, and others, urbanization is often accompanied by an increase in the number of automobiles, expansion of industrial zones, and growth in the number of domestic heating systems (Makhmutov T. et al, 2024). This results in intensive emission of harmful substances into the atmosphere, such as nitrogen dioxide, carbon oxides, and others. As a result, serious air pollution occurs, negatively impacting the health of urban residents and the environment.

Materials and methods

The theoretical and methodological basis of the study is the systemic method, which ensures a comparative and comprehensive analysis of measures to analyze the quality of air, water, and soil in various regions of the Zhambyl region, the use of resources to assess the level of pollution and sources of pollution. Traditional and modern methods were used in writing the article: comparative, historical, statistical, as well as remote sensing data and GIS technologies.

Data on atmospheric pollutant emissions was obtained from official reports and statistical bulletins (Bulletin, 2022), including the State of Atmospheric Air Protection in the Zhambyl Region (2013–2022), published by the Bureau of National Statistics. This data includes information on emissions by type, volume, and distribution across urban areas such as Taraz city and Zuali district.

Results and discussion

Environmental problems in the cities of Kazakhstan include air pollution, surface water pollution, and an imperfect waste management system. In 10 cities of Kazakhstan, such as Astana, Almaty, Karaganda, Temirtau, Atyrau, Aktobe, Balkhash, Ust-Kamenogorsk, Zhezkazgan, and Shymkent, a high level of atmospheric air pollution is observed. This is due to emissions from industrial enterprises, thermal power plants, and motor vehicles. Other environmental problems include pollution of water resources, landslides, and changes in overall biological productivity. Kazakhstan also faces issues such as radiation from nuclear test sites, the drying up of the Aral Sea, and the desertification of former agricultural lands.

To mitigate environmental issues in Kazakhstan, a multi-faceted approach is required (Bulletin, 2022). This includes reducing emissions from industrial activities, decreasing the number of vehicles powered by internal combustion engines, enhancing exhaust gas purification, and transitioning to electric vehicles(Scientific and Practical Conference, 2018). Furthermore, it is crucial to strengthen oversight over emissions from industrial facilities, thermal power plants, and motor vehicles, as well as to improve waste management systems.

Figure 1 shows the distribution of pollutant emissions into the atmosphere (in tons) across the districts of the Zhambyl region. The highest volume of emissions is observed in the city of Taraz (5,376.476 tons) and Baizak district (28,535.551 tons), which represent the largest shares of emissions in the region.

The distribution of emissions across other districts of the Zhambyl region is as follows:

- Kordai district (4,226.320 tons),
- Shu district (2,031.872 tons),
- Sarysu district (1,925.123 tons),
- Moiynkum district (1,728.135 tons),
- Talas district (721.791 tons),
- Zhulai district (418.031 tons).

The lowest emission volumes are recorded in Merken district (588.204 tons) and Turar Ryskulov district (386.112 tons).

These data emphasize the significant concentration of emissions in major administrative centers and more densely populated areas, such as the city of Taraz and Baizak district.

The city of Taraz is the largest source of emissions, accounting for more than half of the total emissions in the region. Significant emissions are also observed in the Zhualy district. This may indicate the need for stricter control and regulation of industrial and other sources of pollution in these areas.

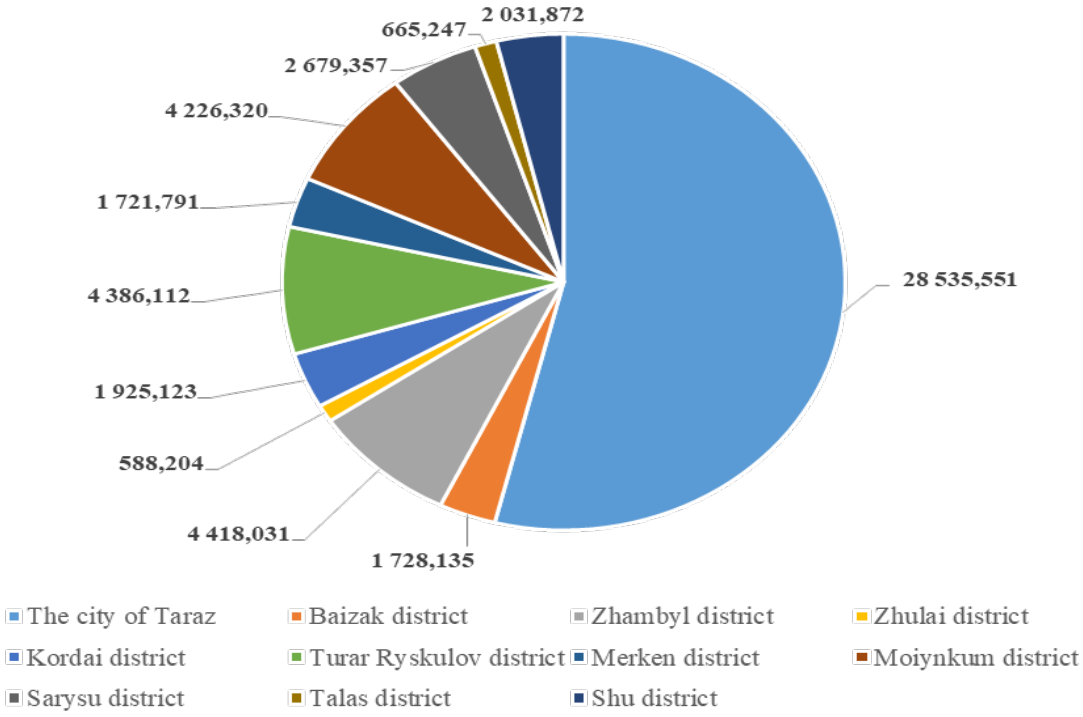

Figure 1 – Emissions of pollutants into the atmosphere (tons)
The source is compiled by the authors based on statistical data from the official website www.kazhydromet.kz.

Emissions are unevenly distributed across districts. Some areas, such as Talas and Merken, have relatively low emissions compared to other districts. This may be due to less industrial development or other factors affecting air pollution (Mahanov K., 2023).

High levels of emissions can negatively affect air quality and the health of residents in the region. This can lead to an increase in respiratory diseases and other illnesses related to air pollution. Therefore, measures are needed to reduce emissions and improve the environmental situation.

Effective control and regulation measures from the government and local authorities are necessary to reduce emissions of pollutants (Shedenov U.K., Myrzaliev B.S., 2015). This may include the implementation of strict environmental safety standards for enterprises, regular monitoring and checks of emissions, as well as encouragement of the use of more environmentally friendly technologies.

Numerous environmental problems of cities, mainly the largest of them, are associated with the excessive concentration of population, transport and industrial enterprises in relatively small areas, with the formation of anthropogenic landscapes, which are very far from the state of ecological balance. On the one hand, urbanization improves the living conditions of the population. On the other hand, it leads to environmental pollution, an increase in the chemical, physical and mental load on the human body. Kazakhstan has a very vulnerable natural environment. The territory of the republic is mainly composed of steppes, semi-deserts and deserts (Semenyuk O. et al., 2023).

Figure 2 illustrates the distribution of sustainable sources of pollutant emissions across various administrative units. The data is categorized by the number of sources within each district and the city of Taraz. The city of Taraz accounts for the highest number of sources (3,718), highlighting its significant contribution to emissions. This is followed by Baizak district (1,362), Zhambyl district (1,325), and Kordai district (1,072), which also show notable emission activities.

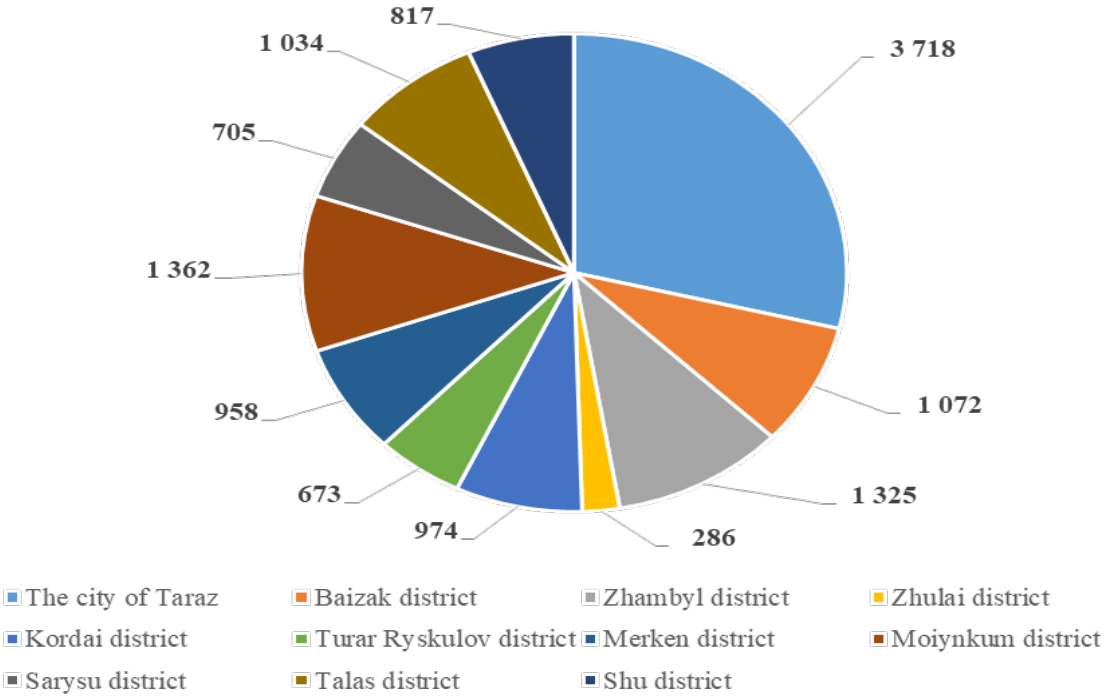

Figure 2 – Number of sustainable sources of pollutant emissions
The source is compiled by the authors based on statistical data from the official website www.kazhydromet.kz.

Smaller contributions are observed in districts such as Merken (958), Shu (817), Turar Ryskulov (705), Moiynkum (673), Sarysu (286), and Zhulai district (974). This variation underscores regional differences in industrial activity, population density, and potential regulatory measures affecting emission levels.

The data can be used to prioritize environmental monitoring and mitigation efforts in high-emission areas while exploring best practices in regions with fewer emissions.

The city of Taraz and the Zhualinsky district are notable for having the highest concentration of sustainable sources of emissions. This correlation may be attributed to the presence of industrial development and other activities that generate pollutants.

The city of Karatau is located 82 km northwest of the city of Taraz, on the northwestern spur of the Karatau mountain range, on the slope of Sholaqty, in the valley between Zhetimshoqy and Aqtau, at 543 m above sea level. The city covers an area of 22.8 km. In 1946, the village of Sholaktau appeared on the site of the current city of Karatau. Thanks to the development of local phosphorite deposits, the village grew rapidly, and in 1963 it was granted the status of a city. The name of the city is given in connection with the name of the nearby Karatau mountain range, which means “Black Mountain” in Kazakh.

The city of Zhanatas is located 170 km northwest of the city of Taraz, which is the administrative center of Zhambyl region, in the northern part of the Karatau mountain range. In connection with the development of a large phosphorus mine, a settlement arose in 1964, and in 1969, it became a settlement. In 1971, the rapidly growing settlement was granted the status of a city. The name of the city is associated with the development of mineral raw materials: translated from the Kazakh language, it means “New Stone”. The presence of phosphorite deposits determined the formation of the cities of Zhanatas and Karatau as resource cities and the directions of their economic development. (Kaimuldinova K. et al., 2024)

The data suggests that the number of sustainable sources of pollutant emissions in the region is proportionally linked to population density and industrial development (Shedanov, U.K., Myrzaliev, B.S., 2022). This could be due to the concentration of enterprises and industrial facilities in cities and the most developed districts, which contributes to increased emissions.

An increase in the number of sustainable sources of emissions may negatively impact the environmental situation in the region (Nurkeev S.S., Musina U.S., 2005). This can lead to increased air, water, and soil pollution, which in turn can affect public health and ecosystems.

Given the increase in the number of sustainable sources of emissions, it is important to ensure effective management and monitoring of them. This includes the implementation of strict regulations and standards to reduce emissions, as well as regular monitoring of the state of the environment (Kazakhstan Today, 2023).

Proactive steps must be taken to decrease the prevalence of sustainable sources of emissions, including encouraging the adoption of eco-friendly technologies and manufacturing practices.

Figure 3 presents the spatial distribution of pollutant emission sources across Zhambyl Region. The map uses a combination of symbols and bar graphs to visualize both the number of emission sources and the total volume of emissions (in tons) for each district.

The highest concentration of emission sources and the largest emission volumes are observed in Zhambyl district and the city of Taraz. These areas are likely to host major industrial activities or urban centers contributing significantly to atmospheric pollution. Conversely, districts like Sarysu and Moiynkum exhibit lower emission volumes, reflecting either fewer emission sources or less industrial activity.

To address the environmental challenges in cities across Kazakhstan, including those in the Zhambyl region, a comprehensive approach is essential. This may involve implementing clean technologies in industry and transportation, enhancing waste management systems, creating green spaces, and raising awareness about environmental issues among the population.

Urbanization, characterized by the increasing urban population, plays a significant role in the economic, political, and cultural development of cities compared to rural areas. In Central Asia, including countries like Kazakhstan, Uzbekistan and Kyrgyzstan there is a notable growth in passenger and freight transport via railways, roads, and air travel (National Statistics Bureau of Kazakhstan, 2019). This growth supports transport and logistics development, facilitating people's movement and goods exchange. Currently, approximately 58% of Kazakhstan's population resides in urban areas. While Kazakhstan has experienced significant urbanization compared to many countries, it has reached an average level due to slower growth in urban population proportion (National Statistics Bureau of Kazakhstan, 2023). The country has 89 urban settlements, with an increasing number of foreign and joint ventures, mainly from Turkey, Uzbekistan, Kyrgyzstan, and China. Urbanization in Central Asia fosters economic progress and regional integration but can also lead to adverse environmental impacts, necessitating measures to preserve nature and ecology amidst urbanization processes (Citypopulation.de, 2022).

Environmental issues in Kazakh cities encompass air and surface water pollution, as well as challenges with waste management. Several cities, including Nur-Sultan, Almaty, Karaganda, and others, face significant air pollution due to emissions from industries, power plants, and transportation. Other concerns include water pollution, landslides, and changes in biological productivity. Kazakhstan also grapples with radiation from nuclear sites, the shrinking of the Aral Sea, and desertification of former agricultural lands (UN DESA, 2021). The deterioration of the environmental situation in Kazakhstan stems from emissions from industrial activities and transportation, outdated sewage treatment facilities, weak state supervision, and inefficient natural resource management.

The environmental state of cities and monotowns in the Zhambyl region presents a complex issue requiring a holistic approach (UNDP, 2019). Pollution from oil and oil products covering vast areas, toxic water from industrial discharges, and challenges with waste disposal are significant problems in the region. Inadequate waste processing, low resource provision, and environmental conditions in monotowns pose environmental risks. Addressing these issues demands effective waste management, environmental improvement in monotowns, and resource enhancement. The results of the study confirm the need to improve the methodology of calculating the integral indices of cities and regions (Suvorov D.M. et al., 2020).

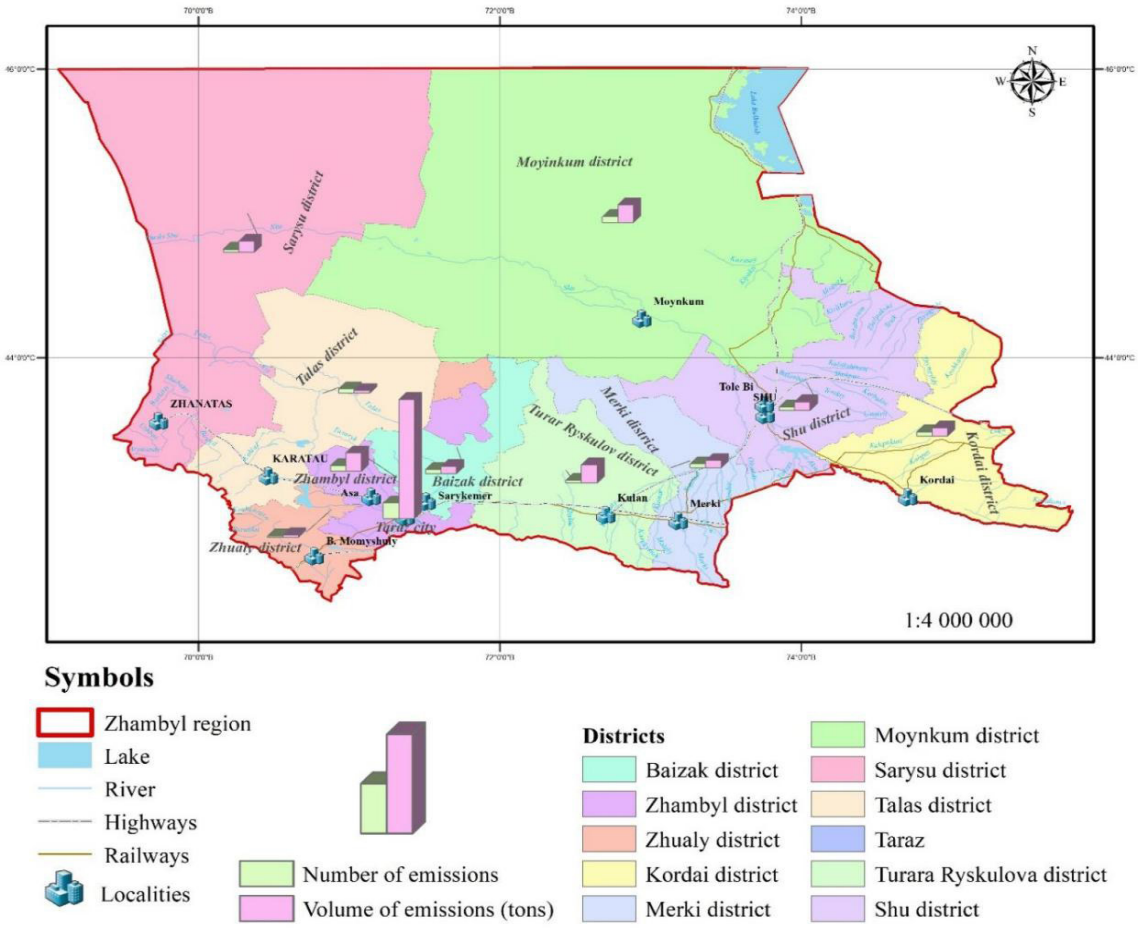

Figure 3 – Sources of pollutant emissions into the atmosphere.
Source: compiled by the authors based on www.kazhydromet.kz (made with ArcGIS 10.8)

In summary, the environmental challenges in Kazakh cities and the Zhambyl region necessitate comprehensive actions, including enhancing treatment facilities, reducing emissions, promoting renewable energy sources, and implementing robust environmental regulations.

Conclusion

The analysis of data on pollutant emissions into the atmosphere in different regions and cities within the Zhambyl region reveals that urban areas, particularly Taraz city and the Zhualy district, are major contributors to emissions. This situation poses significant challenges to air quality, potentially endangering public health.

Data on the number of sustainable emission sources also indicate an increase in industrial activity in some regions and cities of the region. This creates additional environmental problems and requires the implementation of effective control and regulatory measures.

Environmental problems are unevenly distributed throughout the region, requiring differentiated approaches to their solution depending on the specificities of each region and city.

Urban systems in the Zhambyl region need sustainable resource management to balance economic growth with environmental protection. This includes the development and implementation of strategies for energy conservation, improvement of energy efficiency, and the development of environmentally friendly technologies.

Active engagement of society and fostering environmental consciousness among the population are crucial for effectively addressing ecological and geographical challenges. This can be accomplished through educational initiatives, promoting environmentally responsible actions, and engaging public organizations in decision-making processes.

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