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Impact of anthropogenic pollution on the health of the population of East Kazakhstan: Environmental risks and dependent diseases

Gulnaz Sadykanova[1], Sanat Kumarbekuly[2]*, Kulzipa Dakieva[3], San Orazova[1], Bagdat Karmenova[1], Zhamal Igissinova[1], Anargul Sharipkhanova[1], Gauhar Nurzhan[4]

1. Department of biology, Higher School of IT and Natural Sciences, Sarsen Amanzholov University of East Kazakhstan, Ust-Kamenogorsk, Kazakhstan
2. Department of Ecology, Faculty of Forestry, Wildlife and Environment, Kazakh Agrotechnical Research University named after S. Seifullin, Astana, Kazakhstan
3. Department of ecology and geography, Higher School of IT and Natural Sciences, Sarsen Amanzholov University of East Kazakhstan, Ust-Kamenogorsk 070002, Kazakhstan
4. "Educational and Research Ecobiocenter" of the Department of Education for the city of Ust-Kamenogorsk of the Department of Education for the East Kazakhstan region, Ust-Kamenogorsk 070002, Kazakhstan

** Corresponding author's E-mail: sanat_kv@mail.ru*

ABSTRACT
Health assessment in modern times requires the development of effective approaches to identifying changes in the body under the influence of the environment and toxic chemicals emitted by industrial enterprises. Currently, in the industrially developed regions of Kazakhstan, such as the East Kazakhstan region, the impact of anthropogenic factors is increasing, leading to an elevation in the environmental load and adversely affecting the population's health. East Kazakhstan is under significant environmental pressure, negatively impacting the population's health. The combined effects of toxicants on the ecosystem and the human body have not been thoroughly studied. The available literary information is fragmentary, and they do not allow us to draw certain conclusions about the significance of functional systems of the human body in long-term exposure to a complex of harmful toxic substances. At the same time, the existing scientific reports on the importance and necessity of research into the health of the population under the influence of a complex of toxic chemicals emitted by industrial enterprises quite convincingly speak for the tendency of deterioration of the health of the population in the Eastern region of Kazakhstan. The purpose of this study was to generalize and systematize scientific publications with a depth of 15 years (2009-2024) devoted to the study of the impact of anthropogenic factors on the health of the population in industrial regions, using the East Kazakhstan Region (EKR) as an example. An analysis method was used to achieve this goal, within which scientific papers that met the inclusion criteria were assessed. Data sources were PubMed, Google Scholar, and other relevant resources. The target of the research was the impact of anthropogenic environmental factors on the population's health.

Keywords: Environmental pollution, Anthropogenic impact, Heavy metals, Radioactive, Health of population, Diseases.
Article type: Review Article.

INTRODUCTION
Health reflects the state of the ecosystem as a whole, being a generalized indicator of the quality of the living environment and its impact on human life. Anthropogenic factors significantly negatively impact the environment and the health of the population (Chernyshev *et al.* 2022). The study of the biological and medical consequences of anthropogenic pollution and the justification of government measures to improve the population's health is a priority task of government policy in many economically developed countries Human biomonitoring in health

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risk assessment in Europe 2019). According to the Environmental Code and the Code on Public Health, the healthcare system of the Republic of Kazakhstan (Environmental Code of the Republic of Kazakhstan 2021; , Code of the Republic of Kazakhstan 2020) must collect and analyze sufficient data on the health of the population, which is formed under the influence of anthropogenic factors of environmental pollution. These data are necessary for the development of effective measures to prevent eco-dependent diseases. The study of anthropogenic environmental factors on the health of the population is particularly relevant for Kazakhstan, where the ecological situation in several regions is unfavorable and threatening. The country's main environmental problems are related to the development of the mining industry, non-ferrous and ferrous metallurgy, and the increase in vehicles. The concentration of extensive industrial facilities, such as in the East Kazakhstan region, violates the ecological balance of the natural environment. Air pollution is a key threat to human health (Nurmadiyeva & Zhetpisbayev 2018). According to research by Nurmadiyeva G.T., Chistobayev A.I., Gosteyeva S.R., Tazhibayev M.K., and other scientists, ecological stress zones are identified in Kazakhstan, including East Kazakhstan, Abay, Karaganda, Pavlodar, Kostanay, Aktobe regions, as well as the cities of Ust-Kamenogorsk, Semey, Ridder, Karaganda, Khromtau, Kentau, etc. (Chistobayev *et al.* 2012; Tazhibayev 2019). In regions with unfavorable ecological and hygienic conditions, the life expectancy of men in cities is, on average, 1.9 years lower than in territories with a more favorable environmental situation. Life expectancy for women living in relatively ecologically safe cities exceeds the indicators of women from polluted regions by 0.5–2.0 years, on average by 1.3 years (Marenko & Larionov 2014). The average group standardized mortality rates in regions with more favorable environmental conditions are 15.1 per 1000 people for men and 8.2 for women. In ecologically unfavorable areas, these rates are higher: 17.0 and 9.2, respectively. Thus, in regions with a high anthropogenic load on the environment, the indicators characterizing the health of the population are significantly worse (Ibrayeva *et al.* 2019). The high level of morbidity among children and adults in industrially developed regions of Kazakhstan requires a comprehensive study of the impact of unfavorable environmental factors on the population's health. It is necessary to establish measures to minimize the effects of harmful factors (Nurmadiyeva & Zhetpisbayev). One of the pressing environmental problems today is pollution caused by waste from the mining and ore processing industries. The development and exploitation of mineral deposits have a significant and multifold impact on the environment, making this problem important at the global and regional levels (Shkurinsky 2014; Koroleva *et al.* 2019).

MATERIALS AND METHODS

An integrated approach was used to achieve the study's purpose. A set of methods was used to provide a comprehensive analysis of the relationship between anthropogenic pollution of the environment and the health of the population. Particular consideration was given to scientific publications about the East Kazakhstan region, given the high concentration of industrial facilities and high level of pollution. The study used domestic and international scientific publications over a 15-year period (2009–2024), reflecting the impact of anthropogenic factors on the population's health. The primary data sources included scientific journals and articles from international and national databases: PubMed, Google Scholar, Scopus, and Web of Science, which examined the impact of anthropogenic environmental factors on the health of the population; state and departmental reports of the National Statistical Bureau of Kazakhstan, Environmental Code of the Republic of Kazakhstan, Code on Public Health and Healthcare System of the Republic of Kazakhstan, environmental monitoring data from regional environmental services and health inspection services. The integrated approach to the study has provided a deep understanding of the impact of environmental pollution on the health of the population and has helped develop measures to reduce environmental impact and improve the health of the population.

RESULTS AND DISCUSSION

East Kazakhstan Region (EKR) is one of the largest industrial regions of Kazakhstan. There are many mining and metallurgical enterprises, plants for producing non-ferrous and rare metals, and several combined heat and power plants (CHP), burning up to 5,000 tons of coal daily. More than 100 boiler facilities of various capacities add to the overall load on the ecological system. The region's territory experiences a tremendous anthropogenic load: more than 400 thousand tons of harmful substances are thrown into its atmosphere yearly, about 350 million m3 of wastewater is discharged into water bodies, and about 1 billion tons of solid waste has accumulated in storage facilities. Intensive pollution of the environment with various chemical compounds, the main ones being heavy metals, sulfur dioxide, nitrogen oxide, and phenols, as well as highly toxic substances: arsenic, selenium, thallium, mercury, antimony, cadmium, lithium, beryllium, radionuclides lead to their entry into the human body with food, drinking water and ambient air (Sultanbekov *et al.* 2014; Dakieva *et al.* 2023; Boluspayeva *et al.* 2024). According to Mambetkaziyeva R.A. and co-authors, 27% of the balance reserves of lead, 47.7% of zinc reserves, and 47.9% of copper reserves from the total republican volumes are concentrated in the East Kazakhstan region. Forecast resources for the area are 24.8% lead, 56.7% zinc, and 29.3% copper from the total reserves of Kazakhstan (Mambetkaziyeva *et al.* 2011). The key indicators of environmental pollution entering the body through ambient air are suspended matter, carbon monoxide, hydrogen sulfide, hydrocarbons, mercaptans, sulfur dioxide, and nitrogen dioxide. Substances such as chlorides, sulfates, fluorine, hydrocarbons, and vanadium enter the body through drinking water. Lead, copper, zinc, fluorine, and vanadium can enter the body with food products. According to the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, in 2021, emissions of pollutants into the atmospheric air from stationary sources amounted to 128.1 thousand tons, and their level increased by 0.7% compared to the previous year. The main volumes of pollutants were generated in the cities of Ust-Kamenogorsk (53.7 thousand tons), Semey (24.0 thousand tons), Altai district (12.7 thousand tons), Ridder (6.5 thousand tons) and Ayagoz district (5.4 thousand tons). In 2021, the following specific pollutants entered the air basin of the region: lead and its compounds in the amount of 15.0 tons, manganese and its compounds - 3.9 tons, copper oxide - 3.4 tons, sulfuric acid - 183.5 tons, arsenic - 2.8 tons, chlorine - 38.0 tons, mercury - 181 kilograms (Environmental statistics 2024). In 2022, emissions of pollutants into the atmospheric air from stationary sources amounted to 83.3 thousand tons. In 2023, amounted to 80.9 thousand tons. According to the data for 2023, in terms of pollution level, the cities of Ust-Kamenogorsk and Ridder have very high and high pollution levels, the cities of Shemonaikha and Altai have higher pollution levels, while the village of Glubokoe has low pollution levels (Monthly information bulletins on the state of the environment 2024). According to research by Ibrayeva L.K. and co-authors, the complex level of air pollution in the city of Ust-Kamenogorsk, determined by the air pollution index (API 5), was 7.3 conventional units. In certain districts of the city, API values varied from 4.5 (low level) to 12.1 conventional units (high level). The main air pollutant in the city was nitrogen dioxide, which caused a high level of pollution (Ibrayeva *et al.* 2011). The soil's gross content of lead and zinc exceeds background, regional, and Clarke concentrations by tens of times and maximum permissible concentrations (MPC) for soil (Galyamova *et al.* 2013; Mukhametzhanova 2017). According to the assessment of the state of soil pollution with heavy metals in the East Kazakhstan and Abay regions for the spring period of 2024 in Ust-Kamenogorsk, in soil samples taken in various districts, chromium content was within 0.35-0.96 mg kg-1, zinc - 11.40-288.0 mg kg-1, cadmium - 0.38-2.29 mg kg-1, lead - 28.27-214.10 mg kg-1 and copper - 1.04-5.13 mg kg-1(Monthly information bulletins on the state of the environment 2024). According to research by Woszczyk M., significant polymetallic pollution caused by the presence of cadmium, lead, zinc, and copper was recorded in the soil of Ust-Kamenogorsk. The upper soil layers were also characterized by the accumulation of trace metals (Woszczyk *et al.* 2018). According to research by Ibrayeva L.K. and co-authors, the integrated level of soil pollution with metals on average in Ust-Kamenogorsk was 16.2 conventional units (with a range from 1 to 145), which is associated with the long-term operation of industrial facilities of non-ferrous metallurgy (Ibrayeva *et al.* 2015). In Ridder City, surface water and soil's main pollutants were heavy metals, particularly zinc and lead (Kyzyltayeva 2016). Providing the population of Kazakhstan with high-quality drinking water remains a pressing issue (Nurmanova 2012). In the East Kazakhstan Region (EKR), the most polluted areas are located in the zones of influence of industrial and urbanized centers, such as Ust-Kamenogorsk, Zyryanovsk (Altai), Ridder and Glubokoe. The region has accumulated significant volumes of waste from mining and metallurgical, gold ore, non-ferrous metal, rare earth, and rare metal production (Yalaltdinova *et al.* 2014; Aleshina & Muzafarova 2016; Belikhina *et al.* 2017). The Irtysh River is one of the key waterways of Kazakhstan, with about 2.5 million people living in its basin. Large industrial centers such as Ust-Kamenogorsk, Semey, and Pavlodar are located on its territory, where non-ferrous and ferrous mining industries are concentrated. The water balance of the river is complicated by the discharge of insufficiently treated wastewater from industrial plants (Karatayev 2011; Valeyev *et al.* 2015; Kyzyltayeva *et al.* 2016). The Ulba River basin is one of Kazakhstan's most industrially developed regions. Development of the mining and metallurgical industries has increased the pollution of the basin’s surface water with heavy metals, primarily zinc and copper (Yanygina & Anna 2019). The work of N. Zh. Batralina is devoted to studying surface water bodies in Ridder, where chemical pollution was recorded. In the Bystrukha River (Ridder), maximum permissible concentrations (MPC) were exceeded for zinc (4.4 times) and lead (1.1 times). In the Khairuzovka River (Ridder), zinc concentration was 1.8 times higher, and lead concentration was 1.2 times higher than the MPC. In the Glubochanka River, zinc concentration exceeded the MPC by 5.6 times. In the Irtysh River (Glubokoe village), average concentrations of chemical pollutants in most cases were within normal limits, but the zinc level exceeded the MPC by 3.4 times (Batralina 2016). According to research by Sibirkin A.R., pine forest sand of the Semipalatinsk Irtysh Land (East Kazakhstan region, Republic of Kazakhstan) is characterized by an increased content of zinc and lead relative to MPC and regional Clarke (Sibirkina 2011). According to the World Health Organization (WHO), among the ten most dangerous chemicals that affect the environment, workers, and the population, the greatest threat is posed by heavy metals, including mercury, lead, copper, cadmium, arsenic, beryllium and zinc (Yang *et al.* 2017). According to the WHO, about 3 million people around the world die annually from diseases caused by environmental pollution, of which 1.7 million are children under 5 years (Chistobayev *et al.* 2012; Tazhibayev 2019). Pollutants have different effects on human health, which depend on their nature, concentration, and duration of exposure. Short-term exposure to toxic substances in low concentrations can cause symptoms such as dizziness, nausea, throat irritation, and cough. Systematic intake of small doses of toxicants into the body leads to chronic poisoning, while high concentrations can cause acute intoxication, loss of consciousness, or death. It is known that air pollution is one of the key causes of chronic respiratory diseases such as bronchitis and bronchial asthma. In addition, it has an allergic effect and adversely affects the development of children, while up to 12.5% of respiratory diseases are associated with air pollution (Dakiyeva *et al.* 2019; Kerimray *et al.* 2019). Studying the consequences of the anthropogenic accumulation of heavy metals and anthropogenic pollution of the natural environment is critical for public health and safety. It is well known that widespread pollution of the environment with heavy metals significantly impacts human health. Identification of regional patterns of the influence of heavy metals on various functional indicators of the body, as well as the development of methodological approaches to determining quantitative impact (Bityukova & Borovikov 2016; Klepikov *et al.* 2018; Krasilnikova *et al.* 2022), are of great theoretical and practical importance. These studies are necessary to develop effective measures to reduce risks and protect the population's health. According to research by Dakiyeva K.Zh. and co-authors, long-term exposure to chemical stress leads to persistent changes in metabolic processes at the cellular and subcellular levels. These changes reduce the body’s resistance to carcinogenic, mutagenic, teratogenic, and other stress factors. Chemicals' complex effects significantly adversely impact the human body (Dakieva *et al.* 2023). Lead, categorized as the first hazard class, has a polytropic effect on the body. Up to 90% of lead accumulates in bone tissue. In children, the critical organ when exposed to lead can be the brain, while in adults - hematopoietic tissue or kidneys (Mambetalin *et al.* 2015; Chen *et al.* 2022). Lead toxicosis causes damage to hematopoietic organs, nervous systems, sensory organs, kidneys, and digestive and cardiovascular systems. Special consideration should be given to the risks of developing dust bronchitis, bronchopneumonia, and other respiratory diseases that occur when inhaling lead aerosols (Fu & Xi 2020). Copper and zinc, entering the body, primarily affect the respiratory tract, causing respiratory diseases (Krabbe *et al.* 2023). For example, studies by Ibrayeva L.K. and co-authors have shown that in the development of chronic obstructive pulmonary disease (COPD), a significant cause is the high content of pollutants in the atmospheric air of the settlement, along with smoking. In Ust-Kamenogorsk City, the share of COPD was 97% of the total number of respiratory diseases (Ibrayeva *et al.* 2015). Studies by Sraubayev E.N. and co-authors, based on the retrospective epidemiological analysis of the incidence rate in the population living beside the fuel and energy complex of the Republic of Kazakhstan, showed that harmful chemicals contained in emissions have a direct impact on the health of the population. Diseases-markers of unfavorable state of the environment (air pollution) can be bronchial asthma, diseases of the nervous system, neoplasms in children, and glomerular diseases in the region's adult population (Sraubayev *et al.* 2014). Pivina L.M. and co-authors analyzed the prevalence of cardiovascular and respiratory diseases in people living in the East Kazakhstan region. Their results showed that the highest incidence of diseases of the circulatory and respiratory systems, as well as mental and somatoform disorders, is observed in people exposed to direct or indirect radiation exposure [Pivina et al. 2013; , Pivina *et al.* 2018). The study by Ibrayeva L.K. and co-authors confirmed that the identified changes in the health condition of the population in Temirtau, Ust-Kamenogorsk, Taraz, Aktau, and Ekibastuz are pathogenetically associated with air and soil pollution. Based on clinical, hygienic, and statistical data, arterial hypertension and ischemic heart disease are classified as diseases that can develop under the influence of environmental factors (Ibrayeva *et al.* 2019). The study by Namazbayeva Z.I. and co-authors revealed a high dependence of the development of thyroid diseases in adolescents on the content of sulfur dioxide, nitrogen dioxide, and phenol in the atmospheric air and on the content of nickel, lead, cadmium, and cobalt in the soil. Registered changes in the thyroid status of the child population indicate thyroid sensitivity to the effects of unfavorable environmental factors (Namazbayeva *et al.* 2014). Scientific studies confirm that a complex of unfavorable environmental factors has a damaging effect, manifested in immunosuppression and endogenous intoxication. This leads to the suppression of the natural antimicrobial immune response, increased risk of neoplasms, and an elevated number of allergic diseases, which are increasingly called “diseases of civilization” or “environmental diseases.” However, a complete analysis of the state of the immune system is impossible using only traditional methods based on the study of average values of individual indicators. Despite numerous studies, general patterns of the immune system functioning in the process of adaptation to unfavorable environmental conditions remain insufficiently studied. In particular, there is a lack of data on immunological monitoring of the health condition of the population in ecologically unfavorable territories (Gazaliyeva *et al.* 2017). According to results of studies by Tusupkaliyev B.T. and co-authors, the highest blood lead levels were found in school-age children living in regions with industrial plants (Tussupkaliyev *et al.* 2016). Preschool children, being in the process of active growth and development, are most vulnerable to the adverse impact of heavy metals contained in environmental objects. It has been established that even low concentrations of ecotoxicants can cause irreversible harm to the child’s body. In conditions of adaptation to environmental conditions, where the atmospheric air is heavily polluted with heavy metals and toxic chemicals, 42.1% of children were found to have T-lymphopenia, 46.3% B-lymphopenia, and 85.1% elevated IgE levels. These data indicate the active involvement of the children’s immune system in adapting to new environmental and hygienic conditions (Bakhoviddinova & Sakhibova 2024). According to the results of the study by Baidaulet I.O. and co-authors, unfavorable environmental conditions significantly increase the risk of lead accumulation in the body of children living in the third generation in the danger zone. This leads to disturbances in the antioxidant protection of the respiratory system, a decrease in the barrier and protective properties of cellular systems of local immunity, and disturbances in hematopoiesis processes. Hematological signs of lead intoxication include not only a reduction in the number of reticulocytes but also their maturation index (RPI), which is used as an early criterion for the diagnosis of toxic anemia (Baidaulet *et al.* 2013). Intensive air pollution by emissions from the metallurgical industry has a significant negative impact on the physical development of schoolchildren, the level of functional stress in the central nervous system, and nervous-emotional activity. The depressant effect of unfavorable environmental circumstances on the speed of nerve impulses in the central nervous system, development of premature protective inhibition, and decrease in mental performance have been established (Zhumakanova & Aitkulova 2024; Amreyeva & Omirbayeva 2012; Manucci & Franchini 2017). Timely detection of elevated levels of heavy metals in children’s environments allows for effective measures to remove them from the body and prevent further intake. In this regard, monitoring the content of heavy metals in the environment of children in Kazakhstan, which is exposed to significant exogenous stress in different regions of the country, takes on particular significance (Askarov *et al.* 2023). Human activity and industrial development inevitably accompany the consumption of natural resources and environmental pollution. Sustainable nature management and the introduction of measures to reduce the anthropogenic load are essential for maintaining the health of citizens, especially the younger generation (Belikhina *et al.* 2017). Ecosystems that form the health of the population require consistent improvement, especially in the context of increasing pollution by heavy metals and other toxicants, which exceeds the restorative potential of natural systems. The Republic of Kazakhstan, like many countries in the world, faces serious environmental problems that require a government approach and intersectoral cooperation. The introduction of monitoring in the “environment–health” system is a key tool for monitoring the state of the environment and the population's health. Modern methods of analysis, including correlation and regression analyses and using geographic information systems (GIS), allow us to assess the level of environmental risk, identify environmentally dependent deviations in the health condition, and conduct zoning of territories depending on the degree of their environmental comfort. Regional monitoring of the population's health, based on data collection, analysis, and interpretation, helps identify trends and problems associated with the medical and demographic situation and develop reasoned recommendations for improving environmental and social policy. The introduction of information technology in analyzing and managing environmental risks opens up new opportunities for sustainable development (Baimukhambetov *et al.* 2014). Foreign countries' experiences, such as Germany's, show that integrating environmental and medical-demographic aspects into the public administration system helps achieve a balance between economic development and environmental protection (Schulz *et al.* 2007). Kazakhstan has much work to do in this area, which requires strengthening environmental policy, increasing investment in environmental protection measures, and actively participating in the scientific community. Environmental safety issues remain relevant to Kazakhstan and require further attention. A modern scientific approach to assessing and minimizing environmental risks is the key to maintaining the country's population's health and sustainable development.

CONCLUSION

The analysis of the presented literature confirms that the issues of promoting environmental and hygienic safety in modern conditions require an integrated approach. Solutions to environmental problems should be based on a systematic study of the impact of various environmental factors on human health. To achieve sanitary and environmental well-being, it is necessary to reduce the impact of adverse environmental factors, understanding that the complete liquidation of all sources of pollution is impossible. The task is to minimize induced risks to an acceptable level using accurate and effective tools. It is necessary to develop a methodological framework for assessing and managing environmental risks, identify patterns of polluting factors' influence on various body systems, and implement preventive and rehabilitation measures. This will allow timely diagnosis of environmentally dependent diseases and effectively respond to challenges associated with environmental ill-being.

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