

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

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### **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.

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### **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 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 m<sup>3</sup> 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 Mambetkazyeva 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 (Mambetkazyeva *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<sup>-1</sup>, zinc - 11.40-288.0 mg kg<sup>-1</sup>, cadmium - 0.38-2.29 mg kg<sup>-1</sup>, lead - 28.27-214.10 mg kg<sup>-1</sup> and copper - 1.04-5.13 mg kg<sup>-1</sup> (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 Irtys 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 (Batalina 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 (Tusupkaliyev *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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## REFERENCES

- Aleshina, NYu & Muzafarova ASH 2016, Characteristics of the environmental situation in Ridder, East Kazakhstan region (retrospective analysis for 2004-2013). *Occupational Hygiene and Medical Ecology*, 1: 24-31.
- Amreyeva, KE & Omirbayeva SM 2012, Risk assessment of the impact of anthropogenic air pollution on the health of the population in Central Kazakhstan. *Modern Problems of Science and Education*, 6: 196.
- Askarov, KA, Imasheva, BS, Kalmakova, ZhA & Imashev, MS 2023, Impact of the main environmental factors on children's health: Literature review, *Journal of Health Development*, 3: 52, <https://doi.org/10.32921/2225-9929-2023-3-52-18-26>.
- Baidalet, IO, Namazbayeva, ZI, Dosybayeva, GN, Bazelyuk, LT, Sabirov, ZhB & Kussainova, DS 2013, Risk factors for the health of children in intense environmental conditions of lead pollution. *Hygiene and Sanitation*, 6: 64-69.
- Baimukhambetov, KK, Musina, AS & Khabdulina, ZK 2014, Use of risk assessment and management methods in monitoring the state of the environment. *Bulletin of the Kazakh National Medical University*, 3: 52-54.
- Bakhoviddinova, ZM & Sakhibova, MD 2024, Environmental risk factors and children's health condition. *Economy and Society*, 3: 541-546.
- Batralina NZh 2016, State of water resources of the East Kazakhstan region. *Occupational Hygiene and Medical Ecology*, 53: 34-40.
- Belikhina, TI, Pivina, LM, Dyusupov, AA, Semenova, YuM, Manatova, AM & Chayzhunusova, NZh 2017, Methodological framework for organizing medical and ecological studies to assess the health condition of the population of environmentally unfavorable territories of the Republic of Kazakhstan. *Science and Healthcare*, 5: 29-41.
- Bityukova, VR & Borovikov, MS 2016, Ecological state of the regions of Russia and Kazakhstan: measurement possibilities and differentiation factors / *Regional studies*. 2016; 54: 57-80.
- Boluspayeva, L, Jakubus, M, Spsychalski, W, Abzhalelov, A & Bitmanov, Y 2024, Health risk of heavy metals related to consumption of vegetables in areas of industrial impact in the Republic of Kazakhstan: Case study

- for Oskemen. *Biological Trace Element Research*. DOI: 10.1007/s12011-024-04272-8. Online ahead of print.
- Chen, L, Zhao, Y, Liu, F, Chen, H, Tan, T, Yao, P & Tang, Y 2022, Biological aging mediates the associations between urinary metals and osteoarthritis among U.S. adults. *BMC Medical Education*, 20: 207. DOI: 10.1186/s12916-022-02403-3.
- Cherednichenko, VS, Cherednichenko, AV, Cherednichenko, AIV Zheksenbaeva, AK & Madibekov, AS 2021, Heavy metal deposition through precipitation in Kazakhstan Heliyon. 6: e05844. DOI: 10.1016/j.heliyon.2020.e05844. eCollection 2021 Jan.
- Chernyshev, AV, Irzhayev, DI & Zolotukhina, AYU 2022, Level of health of the population as one of indicators of the development of modern society. *Avicenna Bulletin*, 24: 103-12, <https://doi.org/10.25005/2074-0581-2022-24-1-103-112>.
- Chistobayev, AI, Dmitriyev, VV, Semenova, ZA, Ogurtsov, AN & Grudtsyn, NA 2012, Integral assessment and cartographic modeling of public health as indicator of the quality of life. *Maps and GIS in Public Health Research*, pp. 91-104.
- Code of the Republic of Kazakhstan 2020, On the public health and healthcare system. dated July 7, 2020 No. 360-VI ZRK. <https://adilet.zan.kz/rus/docs/K2000000360>.
- Dakieva, KZh, Sadykanova, GE, Tsyganov, AP, Chursin, AS, Sharipkhanova, AS & Egorina, AV 2023, Environmental and industrial impact on the biological systems of living organisms. *Chiang Mai University Journal of Natural Sciences*, 22: e2023015 DOI: <https://doi.org/10.12982/NLSC.2023.015>.
- Dakiyeva, KZh et al. 2019, Trends in the development of changes in the combined effect of chemical compounds on the body. *Bulletin of Semey State University named after Shakarim*, 87: 216-219, <http://rmebrk.kz/magazine/4787#>
- Environmental Code of the Republic of Kazakhstan 2021, Code of the Republic of Kazakhstan dated January 2, 400-VI ZRK. <https://adilet.zan.kz/rus/docs/K2100000400>.
- Environmental statistics 2024, [Electronic resource] – URL: <https://stat.gov.kz/ru/industries/environment/stat-eco/> (date of access: 17.11.2024).
- Fu, Zh & Xi, Sh 2020, The effects of heavy metals on human metabolism. *Toxicology Mechanisms and Methods*, 30: 167-176, DOI: 10.1080/15376516.2019.1701594.
- Galyamova, GK, Zaitsev, VF & Volkova, IV 2013, Zinc in the soil of the city of Ust-Kamenogorsk. *Geography and geoecology of the South of Russia*, pp. 114-119.
- Gazaliyeva, MA, Akhmetova, NSh, Uteubayeva, GZh, Barmenova, AS, Kulikbayeva, AS & Isina, ST 2017, The risk of developing immunodeficiency state and allergopathology in the population of ecologically unfavorable regions of the Republic of Kazakhstan. *Bulletin of KazNMU*, 4: 430-433.
- Guide to comprehensive prevention of environmentally dependent diseases based on risk assessment. Moscow, 2017, 68 p.
- Human biomonitoring in health risk assessment in Europe 2019, Current practices and recommendations for the future. *International Journal of Hygiene and Environmental Health*. 222: 5727-737, <https://doi.org/10.1016/j.ijheh.2019.05.009>.
- Ibrayeva, LK 2014, Influence of environmental factors on the development of diseases in the population. *Occupational Medicine and Industrial Ecology*, 8: 38-43.
- Ibrayeva, LK, Amanbekova, AU, Turgunova, LG & Laryushina, EM 2015, Impact of environmental factors on the development of respiratory diseases among the population of urbanized territories of the Republic of Kazakhstan. *Occupational Medicine and Industrial Ecology*, 3: 29-33.
- Ibrayeva, LK, Rybalkina DKh., Zhanbasinova, NM & Drobchenko, EA 2019, Medical and social losses of years from diseases of the circulatory system in industrial regions of Kazakhstan. *Occupational Medicine and Industrial Ecology*, 59: 444-448.
- Ibrayeva, LK, Rybalkina, DKh, Zhanbasinova, NM & Drobchenko EA 2019, Medical and social losses of years from diseases of the circulatory system in industrial regions of Kazakhstan. *Occupational Medicine and Industrial Ecology*, 59, DOI: <http://dx.doi.org/10.31089/1026-9428-2019-59-7-444-448>.
- Ibrayeva, LK, Uzbekov, VA, Sembayev, ZhKh., Rusyaev, MV & Dikhanova, ZA 2011, Hygienic assessment of air pollution in the city of Ust-Kamenogorsk. *Occupational Medicine and Industrial Ecology*, 6: 13-16.

- Karatayev, MA 2011, Current environmental situation and sustainable development of the Rudno-Altai natural-economic system. *Earth Sciences, All-Russian Journal of Scientific Publications*, 3: 83-87.
- Kerimray, A, Assanov, D, Kenessov, B, Karaca, F 2019, Trends and health impacts of major urban air pollutants in Kazakhstan. *Journal of the Air & Waste Management Association*, 69: 1331-1347, DOI: 10.1080/10962247.2019.1668873.
- Klepikov, OV, Samoilo, AS, Ushakov, IB, Popov, VI & Kurolap, SA 2018, Comprehensive assessment of the state of the environment of industrial city. *Hygiene and Sanitation*, 97: 686-692.
- Koroleva, EG, Rakhimbek, SK & Tupov SS 2019, Medical and geographical aspects of monitoring population morbidity. *Hygiene and Sanitation*, 98: 1285-1295.
- Krabbe, J, Hansen, Ch & Otte, N 2023, Thomas Kraus. Short-term exposure to zinc- and copper-containing welding fumes: Effects on pulmonary function in humans. *Journal of Trace Elements in Medicine and Biology*, 78: 127169, DOI: 10.1016/j.jtemb.2023.127169.
- Krasilnikova, PL, Panev, NI & Korotenko, OYu 2022, Impact of unfavorable production and environmental factors on the population living near industrial plants (literature review). *Medicine in Kuzbass*, 3: 5-12.
- Kyzyltayeva, TA 2016, Comparative ecological-chemical assessment of deposits in water and soil of Glubokoe village and Ridder. *Occupational Hygiene and Medical Ecology*, 1: 62-67.
- Kyzyltayeva, TA, Khanturina GR, Seitkasymova, GZh *et al.* 2016, Ecological and chemical assessment of water resources of territories adjacent to anthropogenic zone. *Occupational Medicine and Human Ecology*, pp. 20-24.
- Mambetalin, ES, Chernenko, IA & Baidenov, ChB 2015, Assessment of the role of heavy metals (Pb, Cd) in the formation of urinary system pathology (using Almaty as an example). *Actual Problems of Transport Medicine*, 2: 89-92.
- Mambetkazyeva, RA, Danilova, AN & Mambetkazyev, EA 2011, Regional features of the natural environment of East Kazakhstan. *Bulletin of KASU*, 6: 35-39.
- Manucci, PM & Franchini, M 2017, Health effects of ambient air pollution in developing countries. *International Journal of Environmental Research and Public Health*, 14: 1048, DOI: 10.3390/ijerph14091048.
- Marenko, YuA & Larionov, VG 2014, Types of anthropogenic pollution of the environment and its impact on the health of urban population as a factor of the national security. *Bulletin of Novosibirsk State University, Series: Social and Economic Sciences*, 14: 27-34.
- Monthly information bulletins on the state of the environment [Electronic resource] – URL: <https://www.kazhydromet.kz/ru/ecology/ezhemesyachnyy-informacionnyy-byulleten-o-sostoyanii-okruzhayuschey-sredy?ysclid=m4fb97k4c75525770> (date of access: 17.11.2024).
- Mukhametzhanova, ZT 2017, Current state of the problem of environmental pollution. *Occupational Hygiene and Medical Ecology*, 55: 11-20.
- Namazbayeva, ZI, Ibrayeva, LK & Benz, TV 2014, State of soil pollution and hormonal status of adolescents. *Bulletin of KazNMU*, 3: 217-219.
- Nurmadiyeva, GT & Zhetpisbayev BA 2018, Impact of the ecosystem on human health in industrially developed regions of Kazakhstan. *Science and Healthcare*, 4: 107-132.
- Nurmanova, ZhA 2012, Issue of providing drinking water to the population of the regions of the Republic of Kazakhstan. *Bulletin of KazNMU*, 1: 421-423.
- Parfiryeva, AYU 2015, Medical and environmental monitoring as a way to assess the quality of the environment. *International Research Journal*, 4: 72-74.
- Pivina, LM, Aukenov, NE, Shaimardanov, NK, Apsalikov, KN, Belikhina, TI & Masabayeva, MR 2013, Analysis of the prevalence of diseases in the population living in the territories adjacent to the Semipalatinsk Nuclear Testing Site. *Science and Healthcare*, 6: 42-43.
- Pivina, LM, Semenova, YuM, Zhunusov, ET, Bulegenov, TA, Manatova, AM, Belikhina, TI, Aukenov, NE & Zhunusova, T 2018, Incidence and severity of somatoform disorders and increased fatigue in residents of the East Kazakhstan region exposed to radiation due to the activities of the Semipalatinsk Nuclear Testing Site. *Science and Healthcare*. 5: 125-134.
- Schulz, C, Conrad, F, Becker, K, Kolossa Gehring, M, Seiwert, M & Seifert, B 2007, Twenty years of the German Environmental Survey (GerES): Human biomonitoring – Temporal and spatial (West Germany/East



- Germany) differences in population exposure. *International Journal of Hygiene and Environmental Health*, 210: 271-297. <https://doi.org/10.1016/j.ijheh.2007.01.034>.
- Shkurinsky, BV 2014, Methodology of medical and geographical zoning of the territory (using the example of the West Kazakhstan region). *Hydrometeorology and Ecology*, 4: 110-122.
- Sibirkina, AR 2011, Content of heavy metals in the sand of the pine forest of the Semipalatinsk Irtysh Land of the Republic of Kazakhstan. *Bulletin of VSU Series: Chemistry, Biology, Pharmacy*, pp 46-51.
- Sraubayev, EN, Kulov, DB, Serik, B, Zhakenova, SR, Shintayeva, NU, Dauletova, AO Aitmagambetova, SS & Erdesov, NZh 2014, Peculiarities of the health condition of the population living near the fuel and energy complex of the Republic of Kazakhstan. *Bulletin of KazNMU*, 3: 164-167.
- Sultanbekov, ZK, Sembayev, ZhKh, Mukazhanova, AK & Gaisin, AB 2014, Hygienic, environmental characteristics and their impact on the health of the population in ecologically unfavorable areas. *Bulletin of KazNMU*, 3: 231-233
- Tazhibayev, MK 2019, Study of spatial-temporal dynamics of health indicators of the population of the Southern Aral Sea region. *Eurasian Union of Scientists*, 8: 19-21.
- Tazhibayev, MK 2019, Study of spatial-temporal dynamics of health indicators of the population of the Southern Aral Sea region. *Eurasian Union of Scientists*, 8: 19-21.
- Tussupkaliyev, BT, Bermagambetova, SK & Tussupkaliyev, AB 2016, Morbidity and the content of trace elements in the blood of schoolchildren living near chromium plants. *Hygiene and Sanitation*, 95: 655-657.
- Valeyev, TK, Suleimanov, RA, Egorova NN et al. 2015, Materials of ecological and hygienic studies of the quality of water bodies in the territories of the mining region. *Water: Chemistry and Ecology*, 3: 30-33.
- Woszczyk, M, Spsychalski, W & Boluspaeva, L 2018, Trace metal (Cd, Cu, Pb, Zn) fractionation in urban-industrial soils of Ust-Kamenogorsk (Oskemen), Kazakhstan-implications for the assessment of environmental quality. *Environmental Monitoring and Assessment*, 190: 362, DOI: 10.1007/s10661-018-6733-0.
- Yalaltdinova, AR, Baranovskaya, NV & Rikhvanov, LP 2014, Impact of emissions from industrial plants of Ust-Kamenogorsk on the formation of the elemental composition of poplar leaves. *Bulletin of IrSTU*, 2: 108-113.
- Yang, BY, Liu, Y, Hu, LW, Zeng, XW & Dong, GH 2017, Urgency to assess the health impact of ambient air pollution in China. *Advances in Experimental Medicine and Biology*, 1017:1-6. DOI: 10.1007/978-981-10-5657-4\_1.
- Yanygina, LV & Anna, A 2019, Evseeva. Caddisfly Assemblages in Metal Contaminated Rivers of the Tikhaya Basin, East Kazakhstan. *Bulletin of Environmental Contamination and Toxicology*, 102: 316-322. DOI: 10.1007/s00128-019-02561-w. Epub 2019 Feb 6.
- Zhumakanova, KS & Aitkulova SA 2024, Atmosphere and its influence on children. *Universum: Medicine and Pharmacology: Electronic Scientific Journal*, 4, URL: [Mhttps://7universum.com/ru/med/archive/item/17210](https://7universum.com/ru/med/archive/item/17210).