МРНТИ 87.25.02
JEL: I15, Q56, P25
DOI: https://doi.org/10.58732/2958-7212-2024-1-21-35

Economic and health aspects of reducing air pollution in urban environments

Aida Omir[1], Darya Mikhailova[2]*, Dainius Pavalkis[3]

[1]Turan University, Almaty, Kazakhstan
[2] University of International Business named after K. Sagadiyev, Almaty, Kazakhstan
[3]Lithuanian University of Health Sciences, Kaunas, Lithuanian

Abstract

The study aims to assess the current state of the environment, urban pollution levels, and demographic indicators. This comprehensive assessment is crucial for understanding the multifaceted impact of urbanization and industrial activities on public health and environmental sustainability. During the study, a detailed trend analysis of emissions of liquid, gaseous, and solid pollutants was carried out, spanning several years to identify patterns and fluctuations in pollution levels. The study meticulously quantified the types and volumes of pollutants emitted, providing a clear picture of the environmental burden faced by urban areas. The economic aspects of environmental protection costs and their impact on reducing pollutant emissions were considered. Additionally, demographic indicators were examined: the number of births, mortality, and the number of children with special educational development needs, in order to identify the relationship between the level of pollution and public health. The results show that despite increased investment in environmental protection, emissions levels remain high, and negative impacts on public health continue. The main sources of pollution have been identified: industrial enterprises and transport. Recommendations are proposed to improve the environmental situation, including strengthening emissions controls, improving waste management infrastructure, and promoting green technologies. The implementation of these recommendations can help improve the air quality and health of Almaty residents, the sustainable economic development of the city, as well as improve the quality of life of the population.

Keywords: urbanization, sustainable development, air quality, urban management, public health

Қалалық ортада ауаның ластануын төмендетудің экономикалық және денсаулық аспектілері

Омир А.[1], Михайлова Д.И.[2]*, Павалкис Д.[3]

[1] Туран Университеті, Алматы, Қазақстан
[2] К. Сағадиев атындағы Халықаралық Бизнес Университеті, Алматы, Қазақстан
[3] Литовский Университет Наук Здоровья, Каунас, Литва.

Түйін

Зерттеу қоршаған ортаның қазіргі жағдайын, қаланың ластану деңгейін және демографиялық көрсеткіштерді бағалауға бағытталған. Бұл кешенді бағалау урбанизация мен өнеркәсіптік қызметтің қоғамдық денсаулық пен экологиялық тұрақтылыққа көп қырлы әсерін түсіну үшін өте маңызды. Зерттеу барысында сұйық, газ тәріздес және қатты ластаушы заттардың шығарындыларының егжей-тегжейлі тренд талдауы жүргізілді, ластану деңгейінің заңдылықтары мен ауытқуларын анықтау үшін бірнеше жыл бойына жүргізілді. Қоршаған ортаны қорғау шығындарының экономикалық аспектілері және олардың ластаушы заттардың шығарындыларын азайтуға әсері қарастырылды. Сонымен қатар, ластану деңгейі мен халықтың денсаулығы арасындағы байланысты анықтау мақсатында демографиялық көрсеткіштер зерттелді: туылғандар, өлім-жітім және ерекше білім беруді қажет ететін балалар саны. Нәтижелер қоршаған ортаны қорғауға инвестицияның ұлғаюына қарамастан, шығарындылар деңгейі жоғары болып қала беретінін және халықтың денсаулығына кері әсер ететінін көрсетеді. Негізгі ластау көздері анықталды: өнеркәсіптік кәсіпорындар мен көлік. Экологиялық жағдайды жақсарту, оның ішінде шығарындыларды бақылауды күшейту, қалдықтарды басқару инфрақұрылымын жақсарту және жасыл технологияларды ілгерілету бойынша ұсыныстар ұсынылады. Осы ұсынымдарды жүзеге асыру Алматы тұрғындарының ауасының сапасы мен денсаулығын жақсартуға, қаланың тұрақты экономикалық дамуына, сондай-ақ халықтың өмір сүру сапасын жақсартуға ықпал ете алады.

Кілттік сөздері: урбанизация, тұрақты даму, ауа сапасы, қаланы басқару, денсаулық сақтау

Экономические и здоровьесберегающие аспекты снижения уровня загрязнения воздуха в городских условиях

Омир А.[1], Михайлова Д.И.[2]*, Павалкис Д.[3]

[1] Университет Туран, Алматы, Казахстан
[2] Университет Международного Бизнеса имени К. Сагадиева, Алматы, Казахстан
[3] Литовский Университет Наук Здоровья, Каунас, Литва

Аннотация

Целью исследования является оценка текущего состояния окружающей среды, уровня загрязнения городов и демографических показателей. Эта комплексная оценка имеет решающее значение для понимания многогранного воздействия урбанизации и промышленной деятельности на здоровье населения и экологическую устойчивость. В ходе исследования был проведен детальный анализ тенденций выбросов жидких, газообразных и твердых загрязняющих веществ, охватывающий несколько лет, для выявления закономерностей и колебаний уровней загрязнения. Были рассмотрены экономические аспекты затрат на охрану окружающей среды и их влияние на уменьшение выбросов загрязняющих веществ. Дополнительно были рассмотрены демографические показатели: число рождений, смертность и количество детей с особыми образовательными потребностями в развитии, с целью выявления взаимосвязи между уровнем загрязнения и здоровьем населения. Результаты показывают, что, несмотря на рост инвестиций в охрану окружающей среды, уровни выбросов остаются высокими, а негативное влияние на здоровье населения сохраняется. Выявлены основные источники загрязнений: промышленные предприятия и транспорт. Предложены рекомендации по улучшению экологической ситуации, включая усиление контроля за выбросами, улучшение инфраструктуры для управления отходами и продвижение зеленых технологий. Реализация данных рекомендаций может способствовать улучшению качества воздуха и здоровья жителей Алматы, устойчивому экономическому развитию города, а также повышению качества жизни населения.

Ключевые слова: урбанизация, устойчивое развитие, качество воздуха, управление городами, здоровье населения

Introduction

Air pollution in urban areas is one of the most pressing environmental problems of our time, with significant health and economic impacts. As a result of intensive urban growth and industrialization, harmful substances such as nitrogen oxides, sulfur oxides, particulate matter, and carbon dioxide are released into the atmosphere. The primary sources of these pollutants include vehicles and heating systems, which emit significant amounts of contaminants every day, degrading air quality in cities [1].

Research shows that air pollution negatively impacts the productivity of urban residents, leading to a decrease in overall economic efficiency [2]. In addition, deteriorating air quality increases the incidence of illness among the urban population, causing various respiratory, cardiovascular, and cancer diseases [3]. In Europe, according to the European Environment Agency, every year, hundreds of thousands of people die prematurely due to air pollution, hospitalizations are rising, drug costs are rising, and millions of working days are being lost [4]. Economic growth and urbanization are contributing to increased air pollution, which poses complex challenges to environmental management and control. Studies conducted in various countries, including China, show that the fight against air pollution often conflicts with the objectives of economic growth, which requires the search for compromise solutions and the development of differentiated policies that take into account the characteristics of the industrial structure and the level of economic development of different cities [5].

One of the critical areas aimed at improving the environmental situation is the introduction of innovative environmental technologies. The introduction of renewable energy sources, increased energy efficiency, the development of sustainable transport, and the transition to a circular economy play an important role in reducing pollution and improving the quality of life of urban residents [6]. Eco-technologies help mitigate the negative impacts of urbanization and industrialization on the environment by improving the quality of air, water, and soil in urban areas [7].

Essential for reducing air pollution is implementing emission reduction measures, such as the closure of thermal power plants and the elimination of coal boilers, which can significantly reduce emissions of air pollutants and greenhouse gases in cities [8]. City governments play a crucial role in developing and implementing public policies to regulate emissions, enforce fuel standards, and control exhaust emissions [9].

The concept of sustainable development, adopted by the world community, focuses on protecting and restoring ecosystems, sustainable management of natural resources, and introducing environmentally friendly technologies. In the context of urban management, sustainable development implies the harmonization of human activities with natural systems, which allows for meeting the current generation's needs without harming future generations [10].

Thus, effective control of air pollution in urban areas requires an integrated approach, including developing innovative technologies, implementing measures to reduce emissions, and active participation of state and municipal authorities in environmental policy. This will not only improve air quality and public health but also promote sustainable economic development in cities.

Literature review

Air pollution in cities has significant economic consequences. Many researchers have found that air pollution negatively affects the productivity of city residents [11, 12, 13]. In urban areas, the primary sources of air pollution are transport and heating, which emit exhaust gases: nitrogen oxides, sulfur oxides, particulate matter, carbon dioxide, and others [14, 15].

In addition, there are a number of studies that have studied the impact of economic growth on air pollution in cities [16, 17]. Air pollution negatively affects human health, causing various types of diseases, such as respiratory and cardiovascular diseases, as well as cancer [18, 19]. In Europe, air pollution is causing hundreds of thousands of people to die prematurely each year, increasing hospital admissions, requiring more medication, and losing millions of working days. Many developing countries, such as China, are already taking steps to address this problem. China's emissions reduction policies are largely similar to those of the European Union. In many developing countries, the fight against air pollution conflicts with economic growth, creating serious obstacles to further development.

There are several researchers who are actively studying and analyzing the correlations between air pollution and economic growth in their countries. In particular, Chinese scientists propose a differentiated approach to policy development that considers the characteristics of the industrial structure and the level of economic development of different cities. They also put forward a number of policy and management proposals for discussion [20, 21]. Current environmental crises require innovative solutions to be financed and invested in order to improve the world's situation. Environmental investing is supportive and should contribute to environmental sustainability. This may include renewable energies, energy efficiency, sustainable transport, a circular economy, and green eco-technologies.

To protect, restore, and preserve the environment, the concept of sustainable development was adopted, where one of the Sustainable Development Goals for the period until 2030 is dedicated to “protecting, restoring and promoting the sustainable use of terrestrial ecosystems, sustainable forest management, combating desertification, and stopping and reversing reverse land degradation and halt biodiversity loss” (UN, Department of Economic and Social Affairs, Sustainable Development). The concept of sustainable ecology is a complex and evolving field that emphasizes harmonizing human activities with natural systems [22]. This involves meeting human needs without compromising the health of ecosystems and addressing environmental problems such as pollution, overpopulation, and resource depletion. Technology-based solutions are also considered crucial for achieving a sustainable environment [23,24].

The integration of eco-technologies in urban areas plays a critical role in improving environmental sustainability and resilience [25, 26, 27]. These technologies aim to mitigate the negative environmental and human health impacts caused by rapid urbanization and industrialization [28]. By focusing on areas such as water supply and sanitation, air pollution control, waste management, and sustainable mobility, eco-tech contributes to creating green, sustainable, and resilient cities. Strategies include using innovative green technologies to regenerate the urban environment, such as improving

air, water, and soil quality. The urban management concept incorporates these eco-technologies to address climate risks and improve the environmental sustainability of cities, emphasizing the importance of technological advances in restoring natural ecosystems in urbanized areas [29].

One solution to air pollution is to reduce gas pollution in cities by reducing urban green spaces and promoting sustainable technologies [30, 31]. Implementing structural emission reduction measures, such as the closure of thermal power plants and the elimination of coal boilers, can significantly reduce both air pollutant emissions and greenhouse gas emissions in cities [32,33]. City governments play a vital role in developing public policies to regulate emissions, enforce fuel standards, and control exhaust emissions to control air pollution effectively [34].

This article aims to analyze pollutants and demographic indicators in the city of Almaty.

Methodology

This article's methodology is based on a literature review and analysis of secondary panel data. This work included a literature review based on sources from the sources Web of Science, Research Gate, and Google Scholar on the impact of investments in the environment and public health. Figure 1 below shows the general methodology of the study.

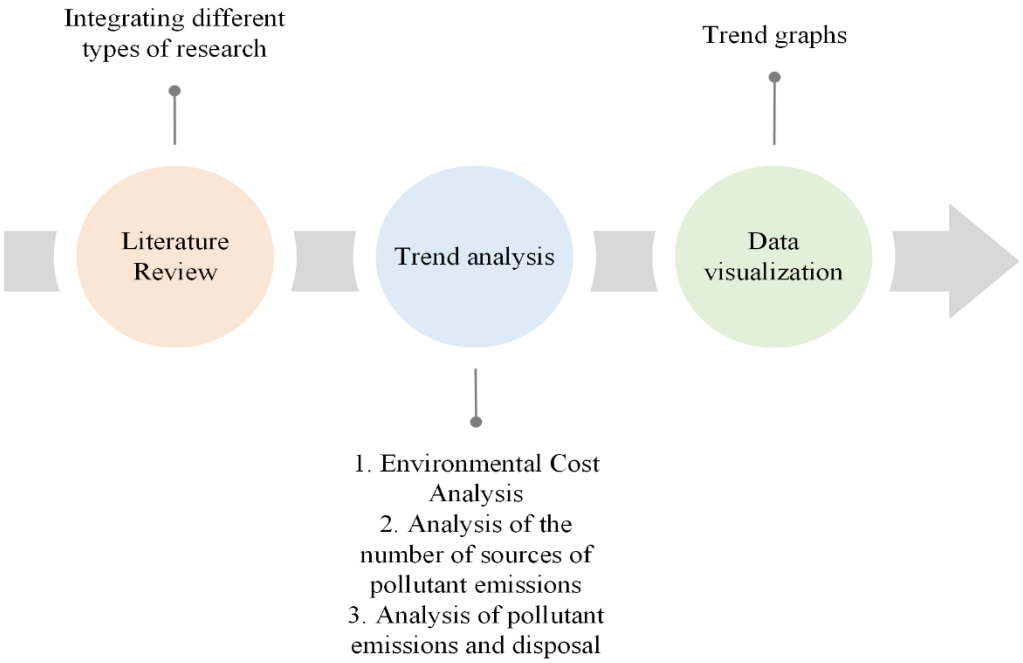

Figure 1. Research Methodology

Note: compiled by the authors

Foreign sources of gas pollution in cities and measures to apply ESG principles in companies were studied. When selecting literature, the key expressions "health economics in urban," "regional disparities," "urban ecosystem," "health outcomes," "health policy in urban," and "ecology in cities" were used. In total, more than 4,000 sources were received. Sources in English and Russian were selected, and the final sample included 23 sources. Next, we used aggregated government data obtained from the database of the Bureau of National Statistics of Kazakhstan.

Data was analyzed and interpreted to determine trends in positive and negative changes in the atmosphere in urban settlements, using the city of Almaty as an example. Trend analysis is an essential tool in statistics and data analysis that can reveal long-term trends and changes in data over time. In the context of the data presented, trend analysis helped determine how pollutant emissions, recycling, environmental costs, and demographics changed from 2012 to 2022.

Results

Research and study of emissions of solid, liquid, and gaseous pollutants, as well as volumes of recycled pollutants, are essential for solving the problem of environmental pollution in the city of Almaty. These indicators help assess the current state of the environment, as well as track progress in environmental protection. Analysis of data on pollutant emissions in the city of Almaty for the period from 2012 to 2022 is presented in Figure 2.

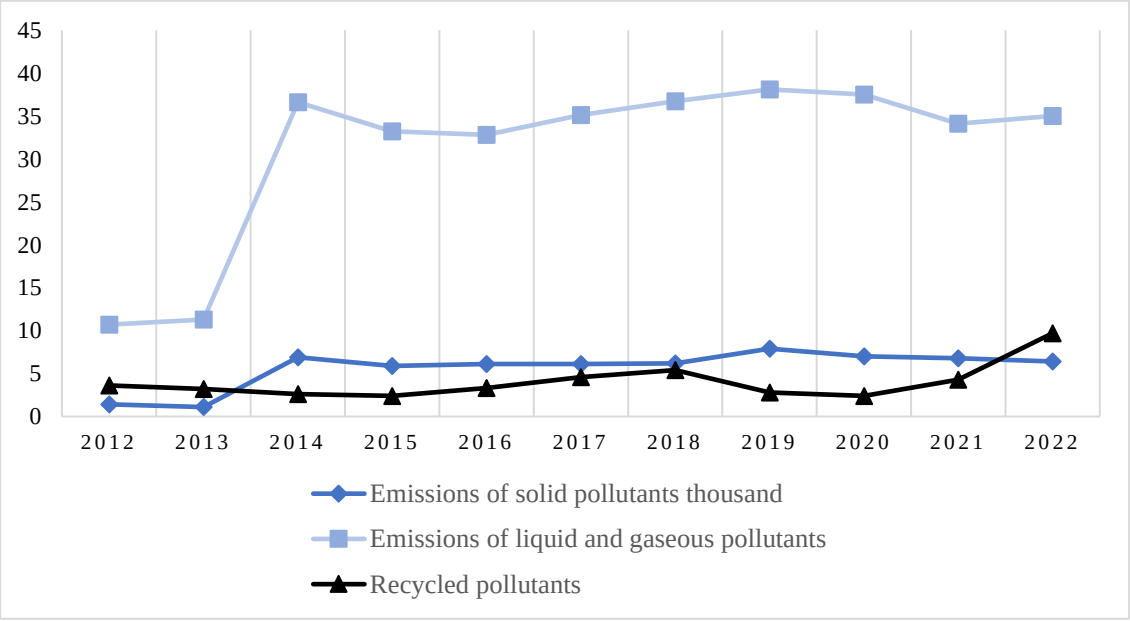

Figure 2. Pollutant emissions and disposal

Note: compiled by the authors based on source [35]

Based on the dynamics of the graph, it is clear that the most significant amount of pollution in Almaty's environment comes from emissions of liquid and gaseous pollutants. There has been an increase since 2012, with the exception of 2020, then the graph goes down, but it is not pronounced. Emissions of liquid and gaseous pollutants enter the environment from various sources, which can be divided into two categories. The first category is stationary sources - industrial enterprises that burn fossil fuels (coal, oil, gas), for example, to produce energy or heat. Also, because of garbage processing, when burned, the substances it produces have a detrimental effect on the urban ecology.

The second category is pollution from transport, and not only from cars. Overall, the graph shows a downward trend since 2012, with the exception of 2021. The environmental problems of the poor-quality city of Almaty lie in many vehicles, which increases yearly. With the increase in cars, the emissions of exhaust gases from gasoline, diesel, and other internal combustion engines increase. In addition to this primary source, the graph shows a less significant source - emissions of solid pollutants. Emissions of solid pollutants include metallurgical emissions: dust, ash, and metal oxides; emissions from construction: cement dust, asbestos, chemical emissions of soot and catalysts.

The level of recycling is significantly lower than the level of emissions of both solid and gaseous substances. The share of recycling ranges from 2.4 to 9.7 thousand tons per year for liquid and gaseous substances, which negatively impacts the environment. It is essential to understand that environmental pollution can lead to the problem of not only smog and acid rain but also have a negative impact on the health of urban residents. Further, Chart 3 presents data on environmental protection costs (thousands of tenge).

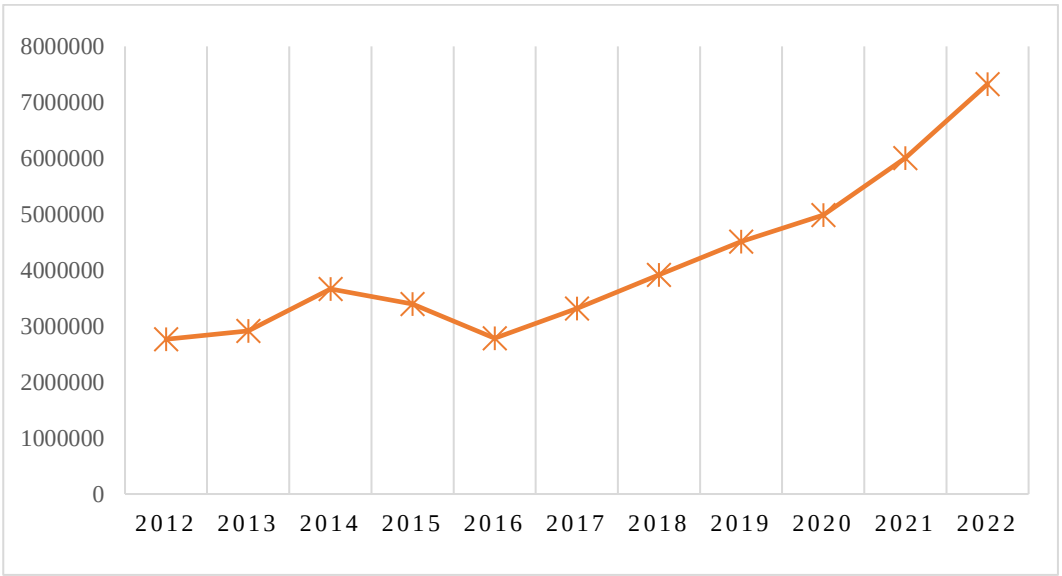

Figure 3. The volume of current costs for environmental protection, thousand tenge

Note: compiled by the authors based on source [35]

The graph shows a steady increase in environmental protection costs for the period from 2012 to 2022, increasing from 2,765,772 thousand tenge in 2012 to 7,326,231 thousand tenge in 2022. This trend indicates increasing government attention to the problem of environmental pollution. However, in this period, there have been years of decreasing costs. In 2015, expenses decreased by 270,928 thousand tenge compared to the previous year, and in 2016, they decreased by another 611,917 thousand tenge. The decrease in costs in these years can be explained by the economic situation, which caused the transition of the tenge to a free-floating regime. This economic context could have a negative impact on the budgeting of environmental programs. Next, graph 4 shows the dynamics of sources of pollutant emissions.

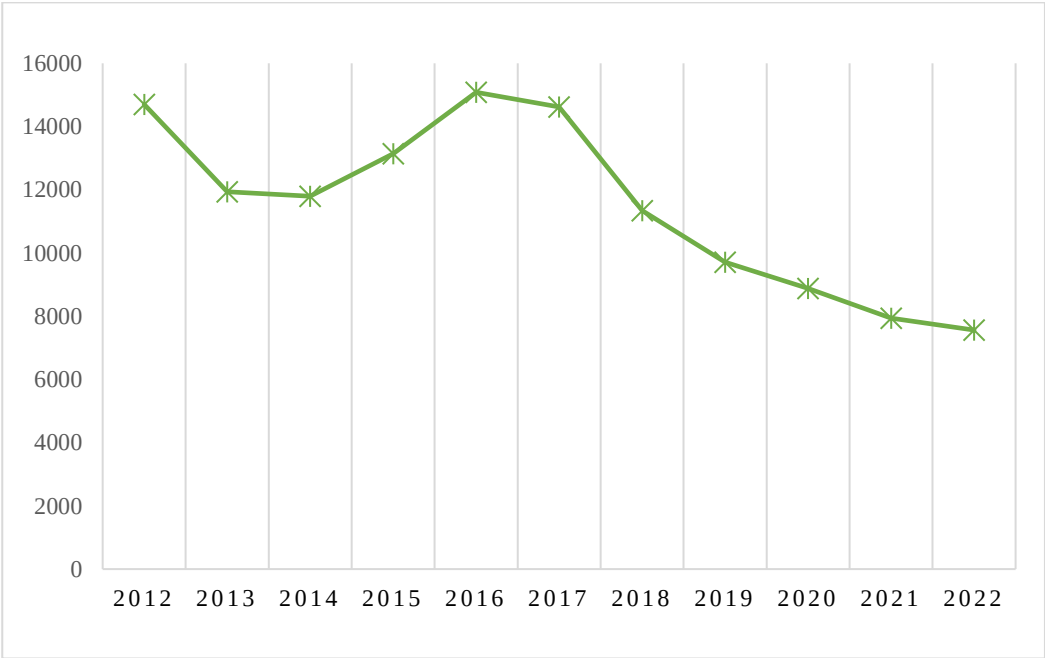

Figure 4. Number of sources of pollutant emissions

Note: compiled by the authors based on source [35]

The graph shows a decrease in the number of sources of pollutant emissions from 2012 to 2022, decreasing from 14,698 thousand in 2012 to 7,561 thousand in 2022. This general trend demonstrates positive dynamics in reducing environmental pollution. However, the period under review also saw years with an increase in the number of emission sources. In 2015, the number of sources increased by 1,341 thousand compared to 2014, and in 2016, this increase was 1,942 thousand compared to 2014. These fluctuations may be due to various factors, including changes in industrial activity and economic conditions.

Based on the provided graphs, one can notice an inverse relationship between the graph trends - an increase in investment in the environment leads to a decrease in the number of sources of pollutant emissions. This indicates increased government attention

to issues of urban environmental protection and increased efforts to solve environmental problems. But despite this, every year, more and more children with disabilities are born in Kazakhstan, and the birth rate is much lower than the death rate (Table 1).

Table 1. Dynamics of demographic indicators and the number of children with developmental disabilities

Year	Number of live births, in person	Number of deaths in person	Number of children with developmental disabilities in person
2012	26838	11230	8543
2013	27311	10819	6634
2014	29672	11049	7640
2015	31159	10579	8933
2016	31704	10794	10876
2017	31423	10935	12155
2018	33259	11678	13870
2019	34308	12240	13287
2020	35526	14440	9246
2021	37922	18220	13842
2022	36110	12221	15828

Note: compiled by the authors based on source [35]

Table 1 shows that the demographic situation in Kazakhstan is complex and ambiguous. There is an increasing trend in the number of live births, with the exception of a slight decrease in 2017 and 2022. The maximum number of births was recorded in 2021, reaching 37,922, which may be due to the COVID-19 pandemic, as many couples were quarantined in 2020. This temporary increase in the number of births indicates the influence of social and economic factors on demographic indicators.

The death toll also shows an overall upward trend, with the highest number of deaths in 2021 at 18,220, also due to complications from the COVID-19 pandemic. In 2022, the number of fatalities decreased to 12,221, which may indicate an improvement in the medical situation and living conditions of the population after the peak of the pandemic. These data highlight the importance of considering health and social factors when analyzing demographics.

The number of children with developmental disabilities also shows an increasing trend, with the exception of 2020, when a decrease was recorded to 9,246 cases. In 2022, this figure peaked at 15,828 cases. Many studies are proving the connection between environmental pollution and the birth of children with developmental disabilities. Emissions of greenhouse gases, heavy metals, nitrogen oxides, and other substances lead to congenital disabilities, low birth weight, congenital lung diseases, developmental delays, and other health problems in children. This highlights the need for strict environmental management to improve the health of future generations.

Conclusion

An analysis of pollutant emissions in Almaty from 2012 to 2022 provides essential information about the state of the city's environment and the effectiveness of current environmental protection measures. The following key conclusions can be drawn from the trend analysis:

Liquid and gaseous pollutants are the primary pollutants affecting Almaty's environment. These emissions have shown an overall increase since 2012, with the exception of 2020, likely due to decreased industrial activity during the COVID-19 pandemic. Despite a slight decline since 2020, emissions levels remain significantly high, requiring enhanced reduction efforts. The primary sources of these pollutants are industrial enterprises and vehicles, which are increasing yearly.

Solid pollutants, although less common than liquid and gaseous pollutants, still pose a significant environmental threat. These include industrial emissions such as dust, ash, metal oxides, and construction pollutants. The trend shows fluctuations, but the overall contribution of solid emissions to pollution remains significant.

Recycling levels of pollutants are significantly lower compared to emission levels. This highlights the need for improved waste management and recycling infrastructure to mitigate the negative impacts of pollution on the environment and public health.

Environmental costs have been steadily increasing, but periods of declining costs in 2015 and 2016, driven by economic difficulties, highlight the vulnerability of ecological program financing to economic fluctuations.

The reduction in the number of sources of pollutant emissions indicates positive dynamics in reducing sources of environmental pollution. However, temporary increases in the number of sources, as in 2015 and 2016, suggest that industrial and economic activity may temporarily reverse these gains. Continued efforts are needed to reduce emission sources further.

Demographic trends and health impacts have shown mixed results, with an overall increase in births and mortality rates. The COVID-19 pandemic has impacted these indicators. The number of children with developmental disabilities is also increasing, and there is evidence of a link between environmental pollution and the development of these disabilities. This highlights the need for strict environmental control to protect public health, especially children.

To solve the identified problems, the following recommendations are offered:

a) Strengthen emission control measures;
b) Improve recycling and waste management;
c) Ensure stable financing for environmental protection;
d) Promote green technologies;
e) Improve public health.

Implementing these recommendations will help Almaty significantly improve its environment's quality and provide its residents with a healthier future.

The Almaty Center for Environmental Problems and the Department of Natural Resources and Environmental Regulation of the city of Almaty can use the results of the analysis of pollutant emissions to develop and implement programs aimed at improving

the city's environmental situation. The Ministry of Health can use these results to create and implement programs to monitor public health and reduce the negative impact of pollutants on health.

Although the study covers the period from 2012 to 2022, additional data over a more extended period could help identify long-term trends and more clearly understand the impact of various policies and actions on air pollution levels. Also, a comparative analysis with other major cities in Kazakhstan or international metropolises with similar environmental problems could provide context for assessing the successes and shortcomings of current environmental protection measures in Almaty. Future researchers should pay attention to exploring the gaps.

References

1. Zivin J. G., Neidell M. The impact of pollution on worker productivity //American Economic Review. – 2012. – Т. 102. – №. 7. – С. 3652-3673. https://doi.org/10.1257/aer.102.7.3652
2. Brook R. D. et al. Particulate matter air pollution and cardiovascular disease: an update to the scientific statement from the American Heart Association //Circulation. – 2010. – Т. 121. – №. 21. – С. 2331-2378. https://doi.org/10.1161/CIR.0b013e3181dbece1
3. Grossberndt S. et al. Public awareness and efforts to improve air quality in Europe //Eionet Report-ETC/ATNI. – 2020. – Т. 2. – С. 17-30.
4. He J., Wang H. Economic structure, development policy and environmental quality: An empirical analysis of environmental Kuznets curves with Chinese municipal data //Ecological Economics. – 2012. – Т. 76. – С. 49-59. https://doi.org/10.1016/j.ecolecon.2012.01.014
5. Geels F. W. Regime resistance against low-carbon transitions: introducing politics and power into the multi-level perspective //Theory, culture & society. – 2014. – Т. 31. – №. 5. – С. 21-40.
6. Uittenbroek C. J., Janssen-Jansen L. B., Runhaar H. A. C. Stimuli for climate adaptation in cities: insights from Philadelphia–an early adapter //International Journal of Climate Change Strategies and Management. – 2016. – Т. 8. – №. 1. – С. 38-56. https://doi.org/10.1108/IJCCSM-06-2014-0069
7. Zhang Q., He K., Huo H. Cleaning China's air //Nature. – 2012. – Т. 484. – №. 7393. – С. 161-162. https://doi.org/10.1038/484161a
8. Polcyn J. et al. Evaluating the influences of health expenditure, energy consumption, and environmental pollution on life expectancy in Asia //International Journal of Environmental Research and Public Health. – 2023. – Т. 20. – №. 5. – С. 4000. https://doi.org/10.3390/ijerph20054000
9. United Nations. (2015). Transforming our world: The 2030 Agenda for Sustainable Development. New York: United Nations.
10. Colglazier W. Sustainable development agenda: 2030 //Science. – 2015. – Т. 349. – №. 6252. – С. 1048-1050. https://doi.org/10.1126/science.aad2333
11. Ren F, Zhu Y, Le D. The Spatial Effect of Air Pollution Governance on Labor Productivity: Evidence from 262 Chinese Cities //International Journal of Environmental

Research and Public Health. – 2022. – T. 19. – №20. – C. 1-25. https://doi.org/10.3390/ijerph192013694

12. Hochman E., Pines D., Zilberman D. The Effects of Pollution Taxation on the Pattern of Resource Allocation: The Downstream Diffusion Case //Quarterly Journal of Economics. – 1977. – T.91. – №4. – C. 625-638.

13. Aragon F.M., Oteiza F., Rud J.P. Climate Change and Agriculture: Subsistence Farmers' Response to Extreme Heat //American Economic Journal: Economic Policy. – 2021. – T. 13. – №1. – C. 1-35.

14. Ning G., Yim S.H., Yang Y., Gu Y., Dong G. Modulations of synoptic and climatic changes on ozone pollution and its health risks in mountain-basin areas //Atmospheric Environment. – 2020. – T. 117808. – №1. – C. 117-131. https://doi.org/10.1016/j.atmosenv.2020.117808

15. Jailaybekov Y., Berkinbayev G., Yakovleva N., Askarov S. Influence of the motor transport emissions on the atmospheric air quality in the city of Almaty and ways of the problem' solution //Sustainable Technologies for Green Economy. – 2022. – T. 2. – №1. – C. 1-24.

16. Nguyen C., Hao W., Wongchoti U. The impact of economic and financial activities on air quality: a Chinese city perspective //Environmental Science and Pollution Research. – 2021. – T. 28. – №7. – C. 1-17. https://doi.org/10.1007/s11356-020-11227-8

17. Munsif R., Zubair M., Aziz A., Zafar M. Industrial Air Emission Pollution: Potential Sources and Sustainable Mitigation //Environmental Emissions. – 2021. – T. 2. – №2. – C.1-15. https://doi.org/10.5772/intechopen.93104

18. Dandotiya, B. Health Effects of Air Pollution in Urban Environment //*Advances in Environmental Engineering and Green Technologies.* – 2019. – T. 1. – №1. – C. 96-115. https://doi.org/10.4018/978-1-5225-7387-6.ch006

19. Kaur J., Jhamaria C., Urban Air Pollution and Human Health: A Review. //*Current World Environment. – 2021.* – T. *16* – *№8. – C. 362-377.* https://doi.org/10.12944/CWE.16.2.04

20. Li Y., Gu F., Zhang T., Delaney J. The Dynamic Relationship Study of Air Pollution and Economic Growth Among 31 Chinese Cities Based on the Multilevel Spatio-Temporal Model //Proceedings of the Twelfth International Conference on Management Science and Engineering Management. – 2019. – T. 1 - №1. – C. 795-806. https://doi.org/10.1007/978-3-319-93351-1_63

21. Wei X., Jiang Y., Gan T. Air pollution and entrepreneurship: evidence from China //Applied Economics. – 2023. – T. 25. – №4. – C.1-15. https://doi.org/10.1080/00036846.2023.2203454

22. Yonglong L., Yichao W., Jingjing Y., Guizhen, H. The ecology of sustainability: Progress and prospect //Acta Ecologica Sinica. – 2019. – T. 39. – №10. https://doi.org/10.5846/stxb201812052661

23. Santos B., Liebl H., Abreu B., Nascimento E., Campos S., Araujo, T. Scope of sustainability in ecological cities //International Journal of Advanced Engineering Research and Science. – 2019. – T. 7. – №6. – C. 675-680. https://dx.doi.org/10.22161/ijaers.6776

24. Simon E., John K., Amin K., Alexandre A. Smarter eco-cities and their leading-edge artificial intelligence of things solutions for environmental sustainability: A comprehensive systematic review //Environmental Science and Ecotechnology. – 2024. – Т. 100330. – №19. – С. 1-32.

25. Errante L. A Green Technological Rehabilitation of the Built Environment. From Public Residential Estates to Eco-Districts //Technological Imagination in the Green and Digital Transition. – 2023. – С. 683-693. https://doi.org/10.1007/978-3-031-29515-7_61

26. Liu Q. Application of remote sensing and GIS technology in urban ecological environment investigation //Arabian Journal of Geosciences. – 2021. – Т. 1743. – №14. – С.1-35. https://doi.org/10.1007/s12517-021-08118-8

27. Nazarov A., Kovtun D., Talu S. Introduction of "Green" Technologies in a Modern City //E3S Web of Conferences 295. – 2021. – Т. 01033. – №2021. – С. 1-5. https://doi.org/10.1051/E3SCONF/202129501033

28. Zaykova E. Nature Restoration Technologies as a Tool for Urbanisation Management //E3S Web of Conferences 263. – 2021. – Т. 05037. – №2021. – С. 1-10. https://doi.org/10.1051/E3SCONF/202126305037

29. D'Amico G., Arbolino R., Shi L., Yigitcanlar T., Loppolo G. Digital Technologies for Urban Metabolism Efficiency: Lessons from Urban Agenda Partnership on Circular Economy //Sustainability. – 2021. – Т. 13 – №11. – С.1-23. https://doi.org/10.3390/su13116043

30. Xiangzhao F., Xianqiang M. Assessment on the Synergistic Effect of China's Urban Air Pollution Control Policies and Greenhouse Gas Emissions Reduction: — Taking Chongqing as a Case Example //Research series on the Chinese dream and China's development path. – 2022. – Т. 11. – №3. – С.165-177. https://doi.org/10.1007/978-981-19-6422-0_11

31. Zhe, Wei. (2023). Impact of Gaseous Pollutants Reduction on Fine Particulate Matter and Its Secondary Inorganic Aerosols in Beijing–Tianjin–Hebei Region. Atmosphere. https://doi.org/10.3390/atmos14061027

32. Wei, Z.; Mohamed Tahrin, N. Impact of Gaseous Pollutants Reduction on Fine Particulate Matter and Its Secondary Inorganic Aerosols in Beijing–Tianjin–Hebei Region // Atmosphere. – 2023. – Т. 14. – №6. – С. 1-24. https://doi.org/10.3390/atmos14061027

33. Commane R., Schiferl L. Climate mitigation policies for cities must consider air quality impacts //Chem. – 2022. – Т. 8. – №4. – С. 910-923. https://doi.org/10.1016/j.chempr.2022.02.006

34. Hughes S., Reducing Urban Greenhouse Gas Emissions: Effective Steering Strategies for City Governments //IMFG Perspectives 16, University of Toronto, Institute on Municipal Finance and Governance. – 2017. – Т. 16. – №4. – С. 1-17. https://tspace.library.utoronto.ca/handle/1807/82861

35. Bureau of National Statistics. Retrieved from: http://www.stat.gov.kz

Information about the authors

Aida Omir – PhD candidate, Turan University, Almaty, Kazakhstan. Email: omir.aida1@gmail.com, ORCID ID: https://orcid.org/0000-0003-4912-1578
***Darya Mikhailova** – student, University of International Business named after K. Sagadiyev, Almaty, Kazakhstan. Email: darya.zsk@gmail.com, ORCID ID: https://orcid.org/0009-0007-3996-6514
Dainius Pavalkis – Professor, Lithuanian University of Health Sciences, Lithuanian. Email: dainpava@gmail.com, ORCID ID https://orcid.org/0000-0001-7339-3237

Авторлар туралы мәліметтер

Омир А. – PhD докторанты, Туран университеті, Алматы, Қазақстан. Email: omir.aida1@gmail.com, ORCID ID: https://orcid.org/0000-0003-4912-1578
***Михайлова Д.И.** – студент, К. Сағадиев атындағы Халықаралық Бизнес Университеті, Алматы, Қазақстан. Email: darya.zsk@gmail.com, ORCID ID: https://orcid.org/0009-0007-3996-6514
Павалкис Д. – профессор, Литва Денсаулық Ғылымдарының Университеті, Литва. Email: dainpava@gmail.com, ORCID ID https://orcid.org/0000-0001-7339-3237

Сведения об авторах

Омир А. – PhD докторант, университет Туран, Алматы, Казахстан. Email: omir.aida1@gmail.com, ORCID ID: https://orcid.org/0000-0003-4912-1578
***Михайлова Д.И.** – студент, Университет Международного Бизнеса имени К. Сагадиева, Алматы, Казахстан. Email: darya.zsk@gmail.com, ORCID ID: https://orcid.org/0009-0007-3996-6514
Павалкис Д. – профессор, Литовский Университет Наук Здоровья, Литва. Email: dainpava@gmail.com, ORCID ID https://orcid.org/0000-0001-7339-3237