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ASSESSMENT OF ENVIRONMENTAL RISKS IN THE REGIONS OF KAZAKHSTAN USING A COMPOSITE INDEX: METHOD AND APPLICATION

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ABSTRACT

The purpose of this study is to develop a methodology for assessing environmental risks and to test it using data on pollution across different regions of Kazakhstan.

Methodology. The study uses a literature review and deductive reasoning to find solutions to environmental pollution. Content analysis helps develop an integrated, weighted environmental risk through composite indexing. Economic and mathematical methods (including Moran's I, spatial weights matrices), along with visualization techniques, are used to present the research results.

The uniqueness of this study lies in its focus on the influence of natural and climate features of a specific region, along with pollution from neighboring areas, rather than relying solely on national pollution indicators and their effects on the regional environment. Data collected and analyzed on emissions and waste in Kazakhstan's four largest regions allowed for the calculation and comparison of environmental risk levels. Regional environmental risk assessments were based on data of the end of 2024. The study revealed that Karaganda (1.26) and West Kazakhstan (1.78) regions experienced high environmental risk during this period, particularly due to the municipal waste index. Meanwhile, in East Kazakhstan, the index, at -0.0142, was considered quite low, and in Kyzylorda, it was closer to the boundary between moderate and high environmental risk (0.198).

The study highlights the importance of quick access to environmental data for guiding management decisions by regional governments. It also stresses the need to expand and sustain this research by developing a regional environmental database. Calculation of environmental risks helps to clarify measures for environmental management in regions adjusting decisions considering the weight of a particular index.

Keywords: environmental risks, regional governance, ESG solutions, pollutant emissions, waste.

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INTRODUCTION

Relevance of the study. In achieving the Sustainable Development Goals (UN SDGs), Environmental, Social, and Governance (ESG) factors are crucial for assessing sustainability and corporate responsibility. Limited information exists on ESG commitments in many countries, particularly in Kazakhstan, where businesses and local governments could improve their evaluation of sustainable practices. Despite government programs aimed at fostering business growth and creating opportunities across various sectors, the efficient use of funds remains inadequate. Regional authorities can benefit from a clearer understanding of the importance of timely project implementation to mitigate environmental risks. However, their ability to reduce environmental risks through effective management is not easily accessible to companies or local officials. Often, regional authorities overlook this potential and the chance to support balanced regional development. Addressing this challenge requires integrating these approaches into not only investment and production sectors but also the social dimensions of regional issues. Meanwhile, the scope of environmental risks is increasing, demanding greater attention from both researchers and managers.

Background Literature. In recent years, there has been increasing attention to environmental risk management. However, researchers involved in planning and public policy note that there is no consistent approach to managing specific environmental risks [1]. Given the expanding range of hazardous substances and sources of environmental pollution, it is essential for regional management that public officials make proactive decisions based on available data [2]. Additionally, the literature on emerging risk management identifies three categories of emerging risks: "new risks," "new and growing risks," and "growing risks" [3,4]. A "new" risk is (i) previously unknown; (ii) previously known but recently reconsidered as a new risk due to changes in knowledge, perception, or evidence; or (iii) a new event or scientific evidence that worsens a known problem, which is considered a risk [4]. A risk is seen as increasing if (i) the number or severity of hazardous events grows, or (ii) the likelihood of greater impacts on people or assets rises, or (iii) the health consequences for workers become more severe than initially expected [5]. This approach is rarely applied in environmental risk management and ESG risks. In this study, this approach was used to evaluate regional environmental risks in Kazakhstan.

Lazar et al. [6] examined the role of environmental risks in the overall risk profile of companies listed on the stock exchange. They propose Climate Value-at-Risk (VaR) and Climate Expected Shortfall (ES) indicators to identify environmental risks for assessing the climate value of stocks. This study assists in developing the applied research methods used in this paper. In particular, the heterogeneity of sensitivity to climate and environmental risk factors across different sectors was convincingly demonstrated. Therefore, healthcare did not show a connection between the rising costs for reducing environmental risks and the improvement in the quality and volume of medical services. The energy sector showed the most significant benefit from enhancing the environmental performance of companies. Shokravi et al. [7] assessed the index of environmental efficiency for various regions, based on an evaluation of macroeconomic indicators and environmental risks for each region. They use an approach to calculating the integrally weighted environmental risk of a specific country or region through the composite indexing. Spatial analysis methods were used: a spatial weight matrix and Moran's I index. These methods are based on the fact that regional environmental risks, being territorial, are interdependent (transferred to neighboring regions). Moreover, the generated environmental data themselves are recognized as spatial, which allows for the use of the weight matrix method. We also used Moran's I index to cluster regions by risk level (Table 1) [8,9]. The results highlighted the need to implement sustainable policies and invest in green projects to improve environmental performance not only within individual regions but also at the national level. They also acknowledge that UNE 150008 and ISO 14001 standards outline the requirements for certifying environmental risk assessments. These standards are based on the probability of each risk and its potential impact on the environment and human health. This helps identify cause-and-effect scenarios and determine possible consequences, allowing for comprehensive environmental risk analysis [10]. This approach was considered in this study and forms the basis of the methodology.

This study aims to identify the main methods for assessing environmental risks and test them using pollution data from Kazakhstan's regions. According to the methodology of the implemented project AR 19678012, four regions of Kazakhstan (West Kazakhstan, East Kazakhstan, Karaganda, and Kyzylorda) were selected as study areas, reflecting common trends in regional management and considering environmental aspects of development. The study also reviews existing literature on approaches to assessing environmental risks related to regional development. The results will help develop recommendations to support ESG management decisions at the local government level, thereby reducing environmental risks. The practical importance of these recommendations allows regional stakeholders to consider them when implementing sustainable management practices. The findings are relevant to a broad audience, as they can be applied both regionally and globally.

Materials and methods. Data collection, content analysis, as well as economic and mathematical research methods (including Moran’s I, spatial weights matrices), will be employed following scientific research practices. Deductive reasoning and visualization of research results will also be used. Specifically, the study will proceed in stages: 1) review the main approaches to identifying environmental risks and their role in ESG management using content analysis, synthesis, and comparison methods; 2) identify the most relevant approaches to assessing environmental risks in regions through content analysis, considering their applicability in Kazakhstan; 3) develop a methodology and test it on regional data; and 4) evaluate the potential applications of this methodology and the factors influencing it, clarifying its feasibility for regional governments. The study hypothesizes that the integrated-weighted environmental risk methodology is most suitable for regional management in Kazakhstan.

Data licensing – environmental risk calculation data was obtained from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, section «Environment», subsection «Environmental Statistics». The data was processed by environmental object type and the most pressing environmental issues in the region, and was classified into a separate table before being used in the calculations. The data was not updated or modified, the environmental risk calculation was performed for 2024.

MAIN PART OF THE STUDY

On a global scale, the environmental component consists of resources that are non-excludable and non-rivalrous for people across all countries and generations, for which humanity as a whole is responsible due to improper use. It's essential to assess the impact of human development on the environment.

Currently, the UN identifies three groups of environmental risks that affect sustainable development:

✓ Environmental deprivation of households – indoor air pollution, inadequate access to clean water and sanitation connected to a water treatment system – is more severe in countries with a low Human Development Index (HDI) and decreases as the HDI increases;

✓ environmental risks affecting communities, such as urban air pollution, tend to increase and then decrease as development as a whole;

✓ environmental risks with global consequences – especially greenhouse gas emissions – usually increase with the HDI [11].

The UN highlights the unequal distribution of the burden of adverse environmental changes, particularly environmental degradation, among different population groups as a key feature of modern development [12]. The main environmental threats identified by UN experts include those primarily related to climate change, such as temperature fluctuations, shifts in rainfall patterns, increased risks of natural disasters, and rising sea levels. In this study, a methodology for calculating the second category of risks—environmental risks affecting communities—will be developed and tested. Therefore, it is crucial to identify relevant and significant environmental risks for a specific region during the management process. A review of various studies, existing practices, and approaches in environmental risk management systematized the process into the following stages.

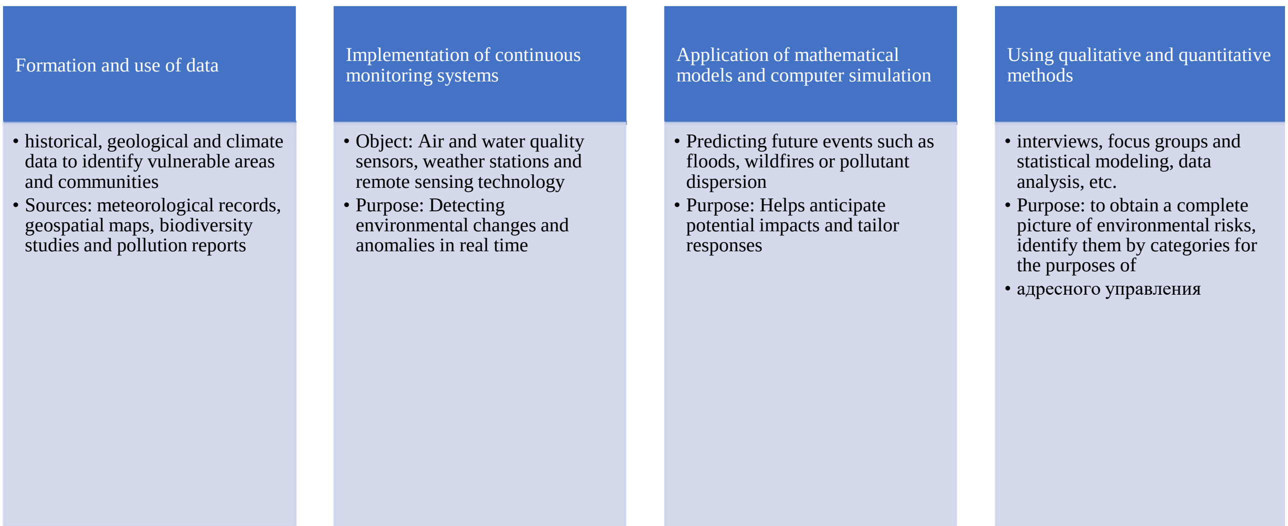

Figure 1 – Environmental Risk Management Process
Note – based on sources [13]

In this study, the following indicators were chosen to evaluate the level of environmental risks related to regional development: pollutant emissions index, pasture degradation index, natural phenomena/disaster index, and municipal waste index. All data were obtained from the Bureau of National Statistics of the Republic of Kazakhstan. According to the ISO 14001 standard, the following formula is used to calculate environmental risks associated with non-compliance with environmental requirements [14].

Environmental risk of an enterprise = number of non-compliant requirements × index of total applied environmental requirements × index of the highest sanction (fines amount) × total environmental requirements applied to the organization's activities.

Environmental risks are threats that result from the impact of economic activity on the environment. Data from 2024, as reported by the Bureau of National Statistics of the Republic of Kazakhstan [15], were used to assess environmental risk. In modern business, where sustainability and responsibility are increasingly important, understanding environmental risks is becoming an essential part of management. Statistics indicate that certain areas of business are more vulnerable to environmental risks than others.

The formula for calculating the integrated-weighted environmental risk of a region in the format of a linear regression equation will look like this:

$$ER_{region} = w_1 * IEmP + w_2 * IDgP + w_3 * IDis + w_4 * IMW \quad (1)$$

where,
IEmP- pollutant emission index
IDgP- pasture degradation index
IDis- natural phenomena/disaster index
IMW – municipal waste index
w_{region} – factor weights
$w_{1region}$ – pollutant emission weight for a specific region
$w_{2region}$ – pasture degradation level weight for a specific region
$w_{3\ region}$– natural disaster level weight for a specific region
$w_{4\ region}$– municipal waste level weight for a specific region

The factor weights (w) play a crucial role in calculating environmental risk, as they determine the extent to which each factor influences the final assessment. The factor weights are adapted for each region based on the frequency of occurrence of phenomena throughout the republic. For example, in the Karaganda region, the weight coefficient of waste and pasture degradation is higher, since there is the largest amount of waste and pasture degradation in the republic, as well as the largest number of pollutant emission.

All indicators are scaled from 0 to 1 to ensure they can be combined correctly. The sum of the weights for each factor should equal 1. For example, in the East Kazakhstan region, the weights are proportional and each equal to 0.25 because the indicators were not overestimated or underestimated compared to other regions of Kazakhstan. It is important to note that most methods use minimum and maximum values for the entire country to assess environmental risk. However, in this case, the maximum and minimum values for neighboring regions were used since they have a greater zonal influence on the occurrence of environmental risks. Indices in environmental risk assessment allow parameters with different units and meanings to be converted to a common scale (such as 0 to 1 or 0 to 100) so they can be compared and incorporated into a single risk formula.

Each index is calculated separately, the formulas for calculating the indices are given below:

The index of pollutant emissions (IEmP) is calculated by the formula:

$$IEmP = \frac{EmP_{fact} - EmP_{min}}{EmP_{max} - EmP_{min}} \quad (2)$$

where,
EmP_{fact}– actual emission in the region
EmP_{min}, EmP_{max} – minimum and maximum values for the sample (by region)

The Index of Pasture Degradation (IDgP) is calculated using the formula:

$$IDgP = \frac{DgP_{fact} - DgP_{min}}{DgP_{max} - DgP_{min}} \tag{3}$$

where,
DgP_{fact} – actual amount of pasture degradation in the region
DgP_{min}, DgP_{max} – minimum and maximum amount of pasture degradation in all regions

The Natural Disaster Index (IDis) is calculated using the formula

$$IDis = \frac{Dis_{fact} - Dis_{min}}{Dis_{max} - Dis_{min}} \tag{4}$$

where,
Dis_{fact} – actual number of natural disasters in the region
Dis_{min}, Dis_{max} – minimum and maximum number of natural disasters in all regions
IMW – index of municipal waste
The index of municipal waste (IMW) is calculated by the formula

$$IMW = \frac{MW_{fact} - MW_{min}}{MW_{max} - MW_{min}} \tag{5}$$

where,
MW_{fact} – municipal waste generation, t/year
$MW_{min,}$ MW_{max} – minimum and maximum boundary values by region

Environmental risk as a neutral indicator, where "0" is a neutral level. The linear regression equation, according to which the level of environmental risk in the region is calculated, is interpreted in such a way that positive values indicate an increase in risk (deterioration of the environmental situation), negative values indicate a decrease in risk (relative improvement and low level of threats). The degree of risk is assessed according to the following categorical scale (Table 1).

Table 1 – Categories of environmental risk

Environmental risk range ER	Category	Interpretation
ER ≤ **- 0.2**	Very low risk	Environmental situation is favorable
-0.2 < ER ≤ **-0.05**	Low risk	Low risk, high resistance
-0.05 < ER ≤ **0.05**	Moderate/neutral	Within normal limits, does not require immediate action
0.05 < ER ≤ **0.2**	Increased risk	Environmental threats are emerging
ER > **0.2**	High risk	Urgent action and monitoring are required

Note – compiled based on data from source [8,9,14].

The conducted research allowed us to collect data based on which the following information was formed regarding the level of weight values on environmental risk components.

Table 2 – Weight coefficients of environmental risk components for regions of Kazakhstan using the composite indexing

Indicators/regions	East Kazakhstan region	West Kazakhstan region	Kyzylorda region	Karaganda region
Neighboring regions	Pavlodar region, Karaganda region, Almaty region	Aktobe region, Atyrau region, Mangistau region	Turkestan region, Karaganda region Aktobe region	Kostanay region, Akmola region, Pavlodar region, East Kazakhstan region, Almaty region, Zhambyl region, Turkestan region, Kyzylorda region, Aktobe region
$w_{1region}$ (EmP)	0,25	0,2	0,2	0,4
$w_{2region}$ (DgP)	0,25	0,25	0,3	0,2
$w_{3region}$ (Dis)	0,25	0,25	0,25	0,1
$w_{4region}$ (MW)	0,25	0,3	0,25	0,2
Note – compiled based on data from source [8,9,15]				

The data shown in Table 2 will serve as a basis for calculating the level of integrated-weighted environmental risk for the studied regions. It should be noted that, within this work, the task was to present and test the methodology for calculating this risk. Since the risk is calculated on a specific date (using the results from 2024), the study does not aim to determine the overall environmental situation in the region (this could be the focus of future research, as it requires collecting more detailed historical data and expanding the number of factors). However, the work presented makes a significant contribution to advancing economic and mathematical methods for assessing environmental risks.

Table 3 – Initial data and methodology for calculating the integrated-weighted environmental risk for the East Kazakhstan region

Indicator	Region Value	Minimum value for neighboring regions	Maximum value in neighboring regions	Calculation Index	Calculation Index
Emissions of pollutants, thousand tons	1680274,1	6406806.1 (Karaganda region)	17566844.8 (Pavlodar region)	1680274,1 – 6406806,1/ 17566844,8 – 6406806,1	- 0,423
Area of degraded pastures, ha	416958	239107.9 (Pavlodar region)	1665650.3 (Karaganda region)	416958 – 239107,9/ 1665650,3 – 239 107,9	0,124
Natural disasters, quantity	15	6 (Pavlodar region)	21 (Karaganda region)	15 – 6/21-6	0,6
Volume of collected municipal waste, tons	160640	269754 (Pavlodar region)	430184 (Karaganda region)	160 640 – 269754/ 574 333 – 269754	- 0,358
Calculation of integrated-weighted environmental risk for East Kazakhstan region	ER=0,25*- 0,423+0,25*0,124+0,25*0,6+0,25*- 0,358 ER= - 0,0142				
Note – compiled based on data from source [15].					

The methodology for calculating the integrated-weighted environmental risk for the East Kazakhstan region, presented in Table 3, indicates that the risk for the East Kazakhstan region was negative, with an ER value of -0.0142. This indicates that, based on the 2024 results, the environmental risk in the East Kazakhstan region is below the base/neutral level, and the level of environmental risk is quite low.

Table 4 – Initial data and methodology for calculating the integrated-weighted environmental risk for the West Kazakhstan region

Indicator	Region Value	Minimum value for neighboring regions	Maximum value in neighboring regions	Calculation Index	Calculation Index
Emissions of pollutants, thousand tons	51452,8	94844.7 (Mangistau region)	323218.1 (Aktobe region)	51452,8 – 94 844,7/ 323218,1 – 94 844,7	- 0,190
Area of degraded pastures, ha	250 653	1 8 7 9 1 8 9 . 3 (Atyrau region)	4960684.0 (Aktobe region)	250653 – 1879189,3/ 4960684,0 – 1879189,3	- 0,528
Natural disasters, quantity	15	2 (Atyrau region)	15 (Aktobe region)	15 – 2/21-15	2,16
Volume of collected municipal waste, tons	177 823	120620 (Mangistau region)	132782 (Aktobe region)	177823 – 120620/ 132782 – 120620	4,703
Calculation of integrated-weighted environmental risk for West Kazakhstan region	ER=0,2*- 0,190+0,25*- 0,528 + 0,25*2,16+0,3*4,703 ER= 1,7809				

Note – compiled based on data from source [15]

The methodology for calculating the integrated-weighted environmental risk for WKR shown in Table 4 revealed that the risk for WKR was positive ER = 1.7809. This suggests that, according to the 2024 data, WKR faces a high environmental risk, mainly due to the municipal waste index's contribution. Based on these findings, it is advisable to conduct an environmental audit in this area, identify pollution sources, and implement restoration measures, at least for the types of environmental triggers analyzed.

Table 5 – Initial data and methodology for calculating the integrated-weighted environmental risk for the Kyzylorda region

Indicator	Region Value	Minimum value for neighboring regions	Maximum value in neighboring regions	Calculation Index	Calculation Index
Emissions of pollutants, thousand tons	23229,7	55561.6 (Turkestan region)	6406806.1 (Karaganda region)	23229,7 – 55561,6/ 6 406806,1–55561,6	- 0,005
Area of degraded pastures, ha	1281687	1665650.3 (Karaganda region)	4960684.0 (Aktobe region)	1281687 – 1665650,3/ 4960684,0 –1665650,3	- 0,116
Natural disasters, quantity	21	15 (Aktobe region)	21 (Karaganda region)	21–15/21–15	1
Volume of collected municipal waste, tons	106 993	132782 (Aktobe region)	430184 (Karaganda region)	106 993 – 132782/ 430184 – 132782	- 0,064
Calculation of integrated-weighted environmental risk for Kyzylorda region	ER=0,2* - 0,005+0,3*- 0,116 + 0,25*1+0,25* - 0,064 ER= 0,198				

Note – compiled based on data from source [15]

Analysis of the data shown in Table 5 indicates that the environmental risk level in the Kyzylorda region is near the borderline between moderate and elevated risk. The study recommends enhancing local monitoring and addressing the most problematic factors, such as those related to the pasture degradation index of 0.116.

Table 6 – Initial data and calculation methodology for the integrated-weighted environmental risk in the Karaganda region

Indicator	Region Value	Minimum value for neighboring regions	Maximum value in neighboring regions	Calculation Index	Calculation Index
Emissions of pollutants, thousand tons	6406806,1	55561.6 (Turkestan region)	17566844.8 (Pavlodar region)	6406 806,1 – 55561,6/ 6 406 806,1– 55561,6	- 0,040
Area of degraded pastures, ha	1665650	239107.9 (Pavlodar region)	4960684.0 (Aktobe region)	1665 650 – 239107,9/ 4960684,0 – 239 107,9	0,302
Natural disasters, quantity	21	6 (Pavlodar region)	43 (Kostanay region)	21 – 6/43-6	0,405
Volume of collected municipal waste, tons	430184	84225 (Zhambyl region)	357213 (Kostanay region)	430184 – 84225 / 357213 – 84 225	1,267
Calculation of integrated-weighted environmental risk for Karaganda region	ER =0,4*- 0,040+0,2* 0,302 + 0,1*0,405+0,2*1, 267 ER = 0, 338				
Note – compiled based on data from source [15]					

Testing the environmental risk calculation method revealed that the Karaganda region faces a higher environmental risk. This highlights the need to monitor risk sources, especially the municipal waste index, which registered a value of 1.267 and contributed most to the overall weighted environmental risk calculation.

Thus, as a result of calculating the environmental risk using the composite indexing in the selected regions of Kazakhstan, the highest increased risk was found in the Karaganda region. The heightened environmental risk in Karaganda highlights the need for priority attention to the municipal waste management system (Table 7). It is also important to establish comprehensive monitoring to identify key pollution sources and implement prompt measures to reduce environmental impact.

Table 7 – Matrix of solutions for potential general risks of business development in the regions of Kazakhstan

Risk	Probability	Type of risk	Strategy	Methods of "minimization/ avoidance"	Alternative solutions
Environmental risk (soil quality, water, chemical pollution, etc.)	Average Impact Average	New and growing risk - there is a possibility of increased impact and new consequences	Minimize	Conduct activities aimed at improving the quality of soil and water, eliminating sources of soil pollution	Reclamation and melioration of disturbed lands for their further use in agriculture
Climate risk (weather conditions, continentality, etc.)	Significant Impact Essential	Growing risk - increase in the scale of hazardous events	Accept	Use of protective means against weathering, increase irrigation during droughts, etc.	Work with the consequences of natural conditions
Refusal of enterprises to implement new technologies to minimize environmental risk	Significant Impact Essential	New risk - appeared as a result of external environmental impact	Minimize and Control	Conduct seminars, round tables, introductory lectures, master classes on project management	Introduce penalties at the legislative level, make changes, tighten the Environmental Code of the Republic of Kazakhstan

Top managers of enterprises and heads of departments are not sufficiently competent in the field of sustainable development	Significant Impact Essential	New and growing risk - there is a possibility of increased impact and new consequences	Minimize and Control	Improve the qualifications of employees of the enterprise and the head of the organization, take seminars, courses, etc.	Hire another manager and update the team of qualified specialists
Absence of stakeholders in assessing and eliminating environmental risk	Average Impact Average	New and growing risk - there is a possibility of increased impact and new consequences	Minimize	Increase environmental literacy of the population, conduct advertising and social events	Search for foreign sponsors
Absence of specialists in the enterprise staff to calculate indicators of sustainable development and environmental risk, including climate risks	High Impact High	New risk - appeared as a result of external environmental impact and internal restrictions	Minimize and Control	Hire specialists to calculate the carbon footprint of indicators of sustainable development and environmental risk, including climate risks	Invite a specialist on a contractual basis to calculate indicators of sustainable development and environmental risk, including climate risk and carbon footprint
Note – compiled by the authors based on data from tables 3,4,5,6					

The findings highlight the importance of using economic and mathematical models to support ESG management decisions, especially for calculating integrated-weighted environmental risk.

Results and discussion. The study shows that many experts identify certain groups of ESG factors that impact the effectiveness of environmental risk management in the region. Therefore, environmental consequences caused by the activities of economic entities—ranging from individuals and businesses to the government and its organizations and institutions—affect their chain of effects. For example, climate change, desertification, deforestation, and loss of biodiversity lead to droughts, floods, crop failures, tornadoes, hurricanes, earthquakes, and other natural disasters. As a result, this causes asset losses for counterparties, impacting their solvency and ability to service loans, which can lead to bankruptcy. In the supply chain, this ultimately results in failure to meet obligations to the government in taxes, to employees in jobs and wages, and to creditors and investors—each of whom ultimately loses assets.

If we consider another aspect of the negative impact—regulatory—using the example of greenhouse and non-greenhouse gas emissions that cause air pollution, we see the other side of this issue. For instance, exceeding emission and air pollution standards results in stricter legislative measures for the polluting company; quota limits are reduced, and activities can even be banned. Additionally, this leads to increased fines, which, collectively, can cause loss of business partners. All these negative effects contribute to economic instability in the region.

At the same time, environmental risks linked to nearly any economic activity—such as reduced energy efficiency, higher energy use, and inefficient water use and losses—have broader implications for regional development. These risks can create conflicts with responsible consumption best practices in supply chains. Such issues can lead to lower benefits, tariff changes, increased costs, and possible damage to reputation. This may result in losing key contracts, diminished government support, and non-compliance with investor or lender requirements for financing, potentially leading to a loss of investment.

Certain industries and technologies need to set up processes for removing hazardous waste. Since hazardous waste creates environmental dangers that can cause human-made disasters, it can result in asset loss in affected areas and often lead to the suspension or restriction of production and business activities. These issues can interrupt technological and business operations, causing supply chain failures and making it harder to meet commitments to stakeholders. Additionally, the depletion of natural resources highlights the need for research and innovation in creating eco-friendly products and services. This, in turn, promotes the development of innovative resource-saving technologies, potential changes in legal rules, and forces companies to update and modernize their technologies. As a result, these adjustments can lead to a loss of market share, shifts in the customer base, and higher costs—sometimes driven by a shift in investment priorities toward organizations that support the creation and growth of ecosystems.

All factors identified during the study emphasize the importance of considering them when interpreting the values of the integrated-weighted environmental risk. Additionally, after determining the risk level, it is necessary to assess its impact and distribution. This might involve using risk matrices and tools such as environmental impact analysis (EIA) and risk and vulnerability analysis (RVA). As a result, this includes creating risk maps that illustrate the spatial distribution of environmental risks, help identify critical areas, and prioritize mitigation measures. Regarding the applicability and effectiveness of approaches to environmental risk management at the regional level, it is recommended that local executive bodies make decisions regarding ESG control. These actions aim to achieve the four goals shown in Figure 2.

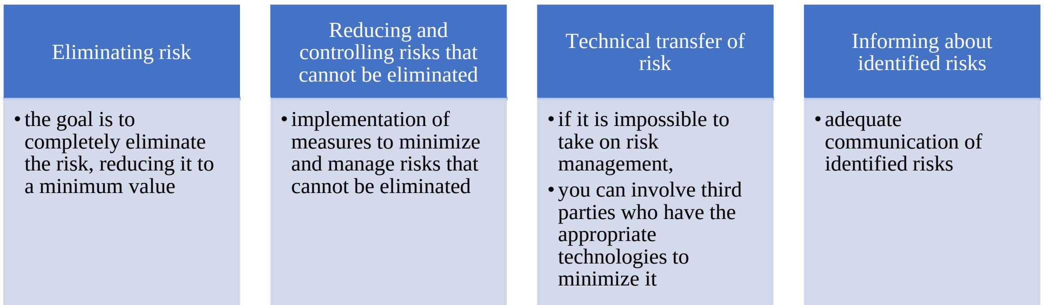

Figure 2 – Key tasks of regional environmental risk management
Note – compiled based on data from source [16]

Against this background, preventing environmental risks is crucial to decrease both the likelihood and impact of such risks while minimizing losses to the regional budget.

The following strategies can be used as prevention methods for regional environmental risks:

– Development of regional environmental policies and regulations that regulate pollutant emissions, promote sustainable use of natural resources, and protect vulnerable ecosystems.

– Promotion of sustainable agricultural, industrial, and urban practices that reduce environmental impacts. This includes using various types of renewable energy, adopting eco-friendly farming methods, managing waste efficiently, and conserving biodiversity, all while considering regional capabilities.

– Implementation of clean technologies that decrease waste and pollution, such as advanced emission filters, biological wastewater treatment, and industrial processes based on circular economy principles.

– Implementation of environmental education campaigns targeting communities, businesses, and governments to promote responsible and sustainable behavior. Training and awareness-raising are essential for encouraging participation in environmental protection.

To minimize environmental risks, it is recommended to develop specific emergency action plans for different types of hazards. These plans should include clear procedures for evacuation, medical aid, protecting critical infrastructure, and communicating with the public. Implementation should be based on projects that establish rapid response teams authorized to act immediately during environmental incidents. These teams need to be equipped with the necessary tools and technology to respond effectively. In the next phase, it is vital to implement regional strategies to restore and rebuild damaged ecosystems, rehabilitate infrastructure, and support affected communities. To ensure success, it is important to identify required resources, including materials and labor. Securing financial resources and establishing their sources for each task is a key priority. Finally, after each event, environmental risk assessments should be conducted to evaluate the effectiveness of response measures and to learn lessons that can improve future preparedness and response.

During the review process, the following recommendations were received for the methodology section of the study: correction of the calibration (anchoring to [0,1] with a neutral value of 0.5 or centering around 0 using z-scores); formalization of the weighting assessment and provision of a sensitivity analysis; description of the WWW (contiguity or distance) and testing for spatial autocorrelation. For reproducibility, it is recommended to make the calculation file (data, code, formulas) publicly available.

In the research results section, was recommended a recalculation with corrected units and normalization (preferably per capita/territory/GDP for robustness). A number of computational inconsistencies reduce validity (e.g., indices <0 or >1, inaccuracies in the denominator/maximum specifications in Tables 3–6, and discrepancies between the calculated environmental risk and categorical labels). Linking the prescriptions to the identified environmental risk factors by region was recommended, as the management matrix is well-designed but was general.

These recommendations will be further developed in future studies. Because these recommendations are useful and helpful, we have included them in the discussion section.

CONCLUSION

This study introduces a new method for calculating an integrated-weighted regional environmental risk, based on an analysis of current practices and considering environmental indicators of regional development in Kazakhstan. The methodology provided allows for justified management decisions aimed at reducing environmental risks. It accounts for the unique characteristics of regional development as well as the influence of similar factors and risks from neighboring regions. The main objectives of the study were to explore approaches and the importance of assessing regional environmental risks, and to test the proposed methodology using environmental data related to regional development. The risk calculation method based on a composite index introduced in this study demonstrated its validity.

The results generally reflect the current situation in the regions and align with external expert assessments. The literature review of advanced research in regional environmental risk management was integrated with the proposed risk calculation approach and was used to interpret the findings. Consequently, recommendations were developed to support the justification of ESG management decisions at the local government level to mitigate environmental risks. The proposed solutions are designed for broad application by various participants involved in regional eco-climate management.

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ҚАЗАҚСТАН АЙМАҚТАРЫНДА ҚҰРАМА ИНДЕКСІН ҚОЛДАНА ОТЫРЫП ЭКОЛОГИЯЛЫҚ ТӘУЕКЕЛДЕРДІ БАҒАЛАУ: ӘДІСТЕМЕ ЖӘНЕ ҚОЛДАНУ

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АҢДАТПА

Зерттеудің мақсаты. Экологиялық тәуекелдерді бағалау әдістемесін әзірлеу және оны Қазақстан аймақтары контекстінде қоршаған ортаның ластануы туралы деректер негізінде сынау.

Әдіснамасы. Жұмыс талдау мен дедукцияны қолдануға негізделген, бұл алдыңғы қатарлы зерттеулердің әдебиеттік шолуының нәтижелерін және мақалада қойылған мәселелерді шешуді байланыстыруға мүмкіндік берді; құрамдас индекстеу арқылы біріктіріп өлшенген экологиялық тәуекелді бағалаудың әзірленген әдістемесін анықтау үшін негіз болған мазмұнды талдауды пайдалану; экономикалық-математикалық зерттеу әдістері (оның ішінде Моран I, кеңістіктік үлес матрицалары), сонымен қатар кестелер мен диаграммалар құру арқылы зерттеу нәтижелерін визуализациялау.

Зерттеудің бірегейлігі, әдетте, экологиялық тәуекелдерді бағалау ластанудың ұлттық көрсеткіштері және олардың аймақтық экологиялық жағдайға әсері негізінде бағаланады, ал ұсынылып отырған әдістеме белгілі бір аймақтың табиғи-климаттық орналасу ерекшеліктерінің әсері мен көршілес аудандардан келетін ластанудың әсерін ескереді. Қазақстанның төрт ірі өңірінің мысалында шығарындылар мен қалдықтардың деңгейін жинау және талдау нәтижесінде алынған мәліметтер экологиялық қауіп деңгейін есептеуге және салыстыруға мүмкіндік берді. Аймақтық экологиялық тәуекелдерді есептеу 2024 жылдың соңындағы деректер негізінде жүргізілді. Зерттеу көрсеткендей, Қарағанды (1,26) және Батыс Қазақстан (1,78) облыстарында осы кезеңде, әсіресе, коммуналдық қалдықтар индексінің үлесіне байланысты жоғары экологиялық қауіп қалыптасқан. Шығыс Қазақстан облысында -0,0142 деңгейіндегі көрсеткіш айтарлықтай төмен деп есептелсе, Қызылорда облысында орташа және жоғары экологиялық тәуекел шекарасына жақын (0,198).

Бұл да аймақтық экологиялық мәліметтер базасын қалыптастыру тұрғысынан осы зерттеуді кеңейту және жалғастыру қажеттілігін көрсетті. Бұл зерттеу экологиялық тәуекелдерді есептеудің осы әдісінің мүмкіндігі мен өміршеңдігін көрсетті. Экологиялық тәуекелдерді есептеу аймақтардың экологиялық менеджменті бойынша шараларды нақтылауға, атап айтқанда белгілі бір көрсеткіштің салмағын ескере отырып шешімдерді түзетуге көмектеседі.

Түйінді сөздер: экологиялық тәуекелдер, аймақтық менеджмент, ESG шешімдері, ластаушы заттардың шығарындылары, қалдықтар

Алғыс: Зерттеу 2023–2025 жылдарға арналған Қазақстан Республикасы Білім және ғылым министрлігінің гранттық қаржыландыру жобасы аясында № AR19678012 «Тұрақты дамудың үштаған тұжырымдамасы (ESG): теңгерімді өңірлік»

ОЦЕНКА ЭКОЛОГИЧЕСКИХ РИСКОВ В РЕГИОНАХ КАЗАХСТАНА С ИСПОЛЬЗОВАНИЕМ КОМПОЗИТНОГО ИНДЕКСА: МЕТОД И ПРИМЕНЕНИЕ

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АННОТАЦИЯ

Цель исследования. Разработать методику оценки экологических рисков и провести ее апробацию на основе данных по загрязнениям окружающей среды в разрезе регионов Казахстана.

Методология. Работа построена на использовании анализа и дедукции, позволивших увязать результаты литературного обзора передовых исследований и решения поставленных в статье задач; контент анализа, послужившего основой для обоснования разработанной методики оценки интегрированно-взвешенного экологического риска посредством композитного индексирования; экономико-математические методы исследования (включая Морана I, матрицы пространственных весов), а также визуализация результатов исследования посредством построения таблиц и схем.

Уникальность исследования заключается в том, что, как правило, оценка экологических рисков расценивается на основе общестрановых показателей загрязнений и их влияния на региональную экологическую ситуацию, в то время как предложенная методика учитывает влияние особенностей природно-климатического расположения того или иного региона и воздействие загрязнений из соседних областей. Полученные в результате сбора и анализа данных по уровню выбросов и отходов на примере четырех крупнейших областей Казахстана, позволило рассчитать и сравнить между собой уровни экологического риска. Расчеты региональных экологических рисков осуществлялись по данным на конец 2024г. Исследование показало, что в Карагандинской (1,26) и ЗКО (1,78) на данный период сложился высокий экологический риск, особенно за счет вклада индекса коммунальных отходов. В то время как по ВКО индекс на уровне - 0,0142 признан достаточно низким, а по Кызылординской области - ближе к границе между умеренным и повышенным экологическим риском (0,198).

В ходе исследования выявлена значимость оперативной доступности к экологическим данным при принятии управленческих решений региональными органами управления. Это также указало на необходимость расширения и продолжения данного исследования с точки зрения формирования региональной базы экоданных. Расчет экологических рисков способствует уточнению мер по экологическому менеджменту регионов, в частности корректировке решений с учетом веса того или иного индекса.

Ключевые слова: экологические риски, региональное управление, ESG -решения, выбросы загрязняющих веществ, отходы

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IMPROVING SUPPLY CHAIN SECURITY THROUGH LOGISTICS RISK MANAGEMENT

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ABSTRACT

Research objective. To conduct a comparative analysis of logistics risks in Kazakhstan and the USA, identifying key vulnerabilities, assessing their impact on supply chains, and developing specialized risk management strategies.

Methodology. A mixed-method approach was used: quantitative analysis (World Bank LPI, trade statistics) and qualitative expert interviews. Applied SWOT analysis, risk mapping, and comparative assessment. Theoretical framework includes Sheffi (2022), ADB/WTO reports, state programs ("Nurly Zhol").

Originality/value. A comparative risk matrix for differently developed economies was created. Practical significance is evidenced by calculations: $2.1B rail gauge standardization reduces delays by 30%; NIST compliance cuts cyber incidents by 70%.

Results. Structural disparities were identified:

- Kazakhstan: infrastructure gaps (22% roads meet standards), geopolitical risks (68% EU transit via Russia);
- USA: cyber threats ($4.3M damage/incident), climate risks ($18B annual losses).

Priority solutions: for KZ – developing "Middle Corridor", for USA – port cybersecurity.

This study contributes to the existing body of knowledge by providing a comparative analysis of logistical risk factors in different economic contexts (notably Kazakhstan and the USA) and proposing a novel integrated theoretical and methodological framework for risk assessment and management tailored for industrial enterprises.

Keywords: logistics risks, supply chain resilience, transit corridors, sanctions exposure, cybersecurity, infrastructure adaptation, comparative analysis.

INTRODUCTION

The primary objective of supply chain management (SCM) is to ensure its security, i.e., to minimize the occurrence of risks within the system. The goal of effective supply chain security is the timely identification and assessment of logistical risks and the prioritization of measures to manage them through multi-level protection.