ENVIRONMENTAL FACTORS INFLUENCING THE DEVELOPMENT OF GEO-ECOLOGICAL MONITORING OF THE RESTORATION OF LAND USED FOR TRANSPORT INFRASTRUCTURE

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Abstract

It has been demonstrated that the development and implementation of geo-ecological monitoring of the restoration of transport infrastructure land, taking into account the influence of environmental factors, is a pressing issue.

The theoretical approaches outline the directions and characteristics of the development and application of elements of geo-ecological monitoring of the restoration of transport infrastructure land. However, issues regarding the development of a comprehensive system for geo-ecological monitoring of the restoration of transport infrastructure land, taking into account the influence of environmental factors in particular, remain unresolved.

The research objective of identifying the environmental factors applicable to geo-ecological monitoring of the restoration of transport infrastructure land has been achieved.

The environmental factors influencing the development of geo-ecological monitoring of the restoration of transport infrastructure land have been identified. This enables the construction of a multi-level system of indicators, the development of an assessment method, and the establishment of a quantitative basis for making informed decisions.

The identified factors provide opportunities to determine attribute information for geoinformation and mathematical modelling, forecasting changes, and developing technology for establishing geo-ecological monitoring of land restoration for transport infrastructure.

Keywords: environmental factors, land restoration, geo-ecological monitoring, transport infrastructure, environmental monitoring, geoinformation systems.

Introduction. The transformational processes currently taking place within the land relations system are characterised by a decline in the efficiency of land use and in the spatial provision of territorial units; an imbalance in stakeholder relations is evident, and opportunities for applying modern technologies to enhance land use are diminishing. These processes are exacerbated by the conduct of aggressive military operations. It should be noted that as a result of Russia's invasion, Ukraine's infrastructure has suffered direct losses amounting to $170 billion. Losses to transport infrastructure are estimated at $38.5 billion, including:

– 26,000 km of motorways damaged or destroyed, amounting to $28.3 billion;
– rail transport – $4.3 billion;
– port infrastructure – $0.85 billion;
– the aviation sector – $2 billion;
– 260,000 vehicles were destroyed or damaged, with total direct losses amounting to $2.2 billion [1].

The consequences of the aggression included the destruction of transport infrastructure, disruption of logistics links, increased economic losses and a decline in passenger numbers, as well as a reduction in investment and attractiveness.

In this process, the issue of identifying and defining environmental factors for the establishment of geo-ecological monitoring of the restoration of transport infrastructure land is of particular relevance. To substantiate these environmental factors, the relevant regulatory framework is applied: the Forest Code of Ukraine of 21 January 1994 № 3852-XII, the Subsurface Code of Ukraine of 27 July 1994 № 132/94-VR, the Water and Land Codes of Ukraine of 6 June 1995 № 213/95-VR, the Laws of Ukraine «On Waste Management» of 20 June 1992 № 2320-IX, «On the Legal Regime of the Territory Affected by Radioactive Contamination as a Result of the Chernobyl Disaster» of 27 February 1991

№ 791a-XII, «On the Protection of the Natural Environment» of 25 June 1991 № 1264-XII, «On the Nature Reserve Fund of Ukraine» of 16 June 1992 № 2456-XII, «On the Protection of Atmospheric Air» of 16 October 1992 № 2707-XII, «On a Moratorium on Clear-Cutting on Mountain Slopes in the Fir and Beech Forests of the Carpathian Region» of 10 February 2000 № 1436-III, «On Game Management and Hunting» of 22 February 2000 № 1478-III, «On High-Risk Facilities» (№ 2245), «On the Animal Kingdom» of 13 December 2001 № 2894-III, «On the Red Book of Ukraine» dated 7 February 2002 № 3055-III, «On Land Protection» dated 19 June 2003 № 962-IV, «On State Control over the Use and Protection of Land» dated 19 June 2003 № 963-IV, «On State Registration of Real Rights to Immovable Property and Encumbrances Thereon» of 1 July 2004 № 1952-IV, «On the Basic Principles of State Supervision (Control) in the Sphere of Economic Activity» of 5 April 2007 № 877-V, «On Environmental Impact Assessment» (Law № 2059), «On Strategic Environmental Assessment» dated 20 March 2018 № 2354-VIII. At the same time, the development and implementation of geo-ecological monitoring of the restoration of land used for transport infrastructure, taking into account the impact of environmental factors, remains a pressing issue.

Justification of existing theoretical approaches. Existing scientific studies present theoretical approaches to defining geo-ecological monitoring. At the same time, the development and implementation of geo-ecological monitoring of land restoration for transport infrastructure require further refinement.

Issues relating to the implementation of environmental monitoring are prominent in scientific research [2–4]. Modern geoinformation systems are used to develop and implement geo-ecological monitoring; their characteristics are set out in [5–7]. The areas and characteristics of the development and implementation of geo-ecological monitoring are outlined in the following works [8, 9].

The proposed environmental monitoring system consists of the following structural components (Table 1).

Table 1

Components of environmental monitoring [10]

Structural elements	Specification
The operation of the state environmental monitoring system	The Law of Ukraine «On the Protection of the Natural Environment» (Articles 20 and 22) provides for the establishment of a State Environmental Monitoring System (SEM) and the monitoring of the state of the natural environment and levels of pollution. These functions are entrusted to the Ministry of the Environment and other central executive bodies, which are entities of the State Environmental Monitoring System, as well as enterprises, institutions and organisations whose activities cause or may cause deterioration of the environment. The main principles of the State Environmental Monitoring System (SEM) are set out in Resolution № 391 of the Cabinet of Ministers of Ukraine dated 30 March 1998 «On the Approval of the Regulations on the State Environmental Monitoring System». Currently, within the State Environmental Monitoring System (SEM), the functions and tasks of observation and information provision are carried out by eight entities of the monitoring system: the Ministry of the Environment, the Ministry of Emergencies, the Ministry of Health, the Ministry of Agrarian Policy, the Ministry of Housing and Communal Services, the State Water Management Agency, the State Forestry Committee, and the State Land Committee. Each of the SES entities monitors those environmental components specified in the Regulations on the State Environmental Monitoring System and in the procedures and regulations on state monitoring of individual environmental components. The State Environmental Monitoring System operates at three levels, organised on a territorial basis: the national level, covering priority areas and monitoring tasks across the whole country; the regional level, covering priority areas and tasks within a specific territorial region; the local level, covering priority areas and monitoring tasks within specific territories subject to increased anthropogenic pressure.
Air quality monitoring	The State Hydrometeorological Service (SHS) monitors atmospheric air pollution in 53 cities across Ukraine at 162 fixed monitoring stations, two mobile monitoring posts and two transboundary transport stations. Observations are also carried out on the chemical composition of atmospheric precipitation and on the acidity of precipitation. The mandatory air quality monitoring programme covers seven pollutants: particulate matter, nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide, formaldehyde (H_2CO), lead and benzo(a)pyrene. Some stations monitor additional pollutants. Analyses are carried out to determine the presence of pollutants in precipitation and snow cover.

Monitoring of inland water quality	The State Hydrometeorological Service (SHS) monitors the hydrochemical status of water at 151 water bodies and conducts hydrobiological observations at 45 water bodies. Data is collected on 46 parameters, enabling the assessment of water chemistry, biogenic parameters, the presence of suspended solids and organic matter, major pollutants, heavy metals and pesticides. Monitoring of chronic water toxicity is carried out at 8 water bodies. Indicators of radioactive contamination of surface waters are determined. The State Environmental Inspectorate (Ministry of Environment) takes water samples and collects data on 60 measured parameters.
Monitoring of coastal waters	The State Hydrometeorological Service (MNS) operates a coastal water monitoring network comprising monitoring stations at wastewater discharge points and research stations located in the coastal areas of the Black and Azov Seas. At the existing stations, measurements are taken of between 16 and 26 hydrochemical parameters of the water and bottom sediments.
Soil monitoring	The State Hydrometeorological Service (SHS) monitors soil contamination of agricultural land by pesticides and heavy metals in populated areas. Samples are taken once every five years; samples for heavy metals in the towns of Kostiantynivka and Mariupol are taken annually. The State Environmental Inspectorate (Ministry of Environment) carries out sampling at industrial sites across the country. The total number of parameters measured is 27.
Monitoring of biodiversity indicators	Due to limited budgetary funding, monitoring is carried out only for species of commercial interest (trees, fish, game). Enterprises under the State Forestry Committee monitor forest vegetation in 24 regions of the country. Assessments are carried out of biomass and damage caused to it by biotic and abiotic factors; game fauna and biodiversity; and radiological measurements. Some studies are carried out with international assistance or within the framework of international programmes.
Radiation monitoring	The State Hydrometeorological Service (SHS) monitors atmospheric radioactive contamination by taking daily measurements of gamma radiation exposure doses (GRE), the deposition of radioactive particles from the atmosphere, and the concentration of radioactive aerosols in the air. Measurements of radioactive contamination in surface waters are carried out at eight water bodies. Near nuclear power stations, the State Hydrometeorological Service measures radioactive contamination of surface waters with caesium-137 and soil contamination.

The theoretical approaches outline the main directions and characteristics of the development and application of geo-ecological monitoring elements for the restoration of transport infrastructure land. However, questions remain unresolved regarding the development of a comprehensive system for the geo-ecological monitoring of transport infrastructure land restoration, particularly in view of the influence of environmental factors.

The aim of the study is to identify the environmental factors used for geo-ecological monitoring of the restoration of transport infrastructure land.

Main section. In the context of the development of land relations and ensuring the functioning of transport infrastructure, resolving issues related to the implementation of environmental and safety measures is of particular importance. In recent years, fluctuating trends have been observed in the capital investment index for environmental protection (Fig. 1).

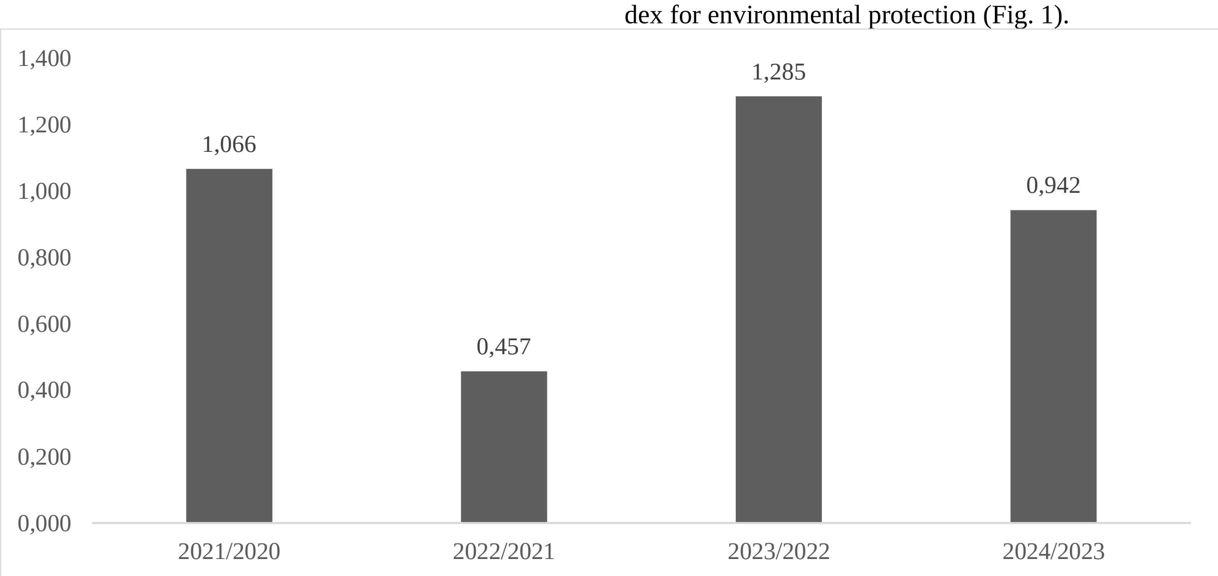

Fig. 1. Trend in the index of capital investment in environmental protection, relative units, according to [11]

In particular, in 2021, compared with 2020 (the 'pre-war' period), there was an increase in capital investment in environmental protection. This indicates positive developments in the implementation of environmental policy. In 2022, as a result of Russia's aggression, a significant decline in this indicator was observed. This is the lowest value for the period under review. In 2023, compared to the previous year, there is a certain 'adaptation' to existing conditions, with capital investment in environmental protection increasing by 28.5%. In the subsequent period under review, this indicator fell by 5.8%.

The trend in the current environmental protection investment index is shown in Figure 2.

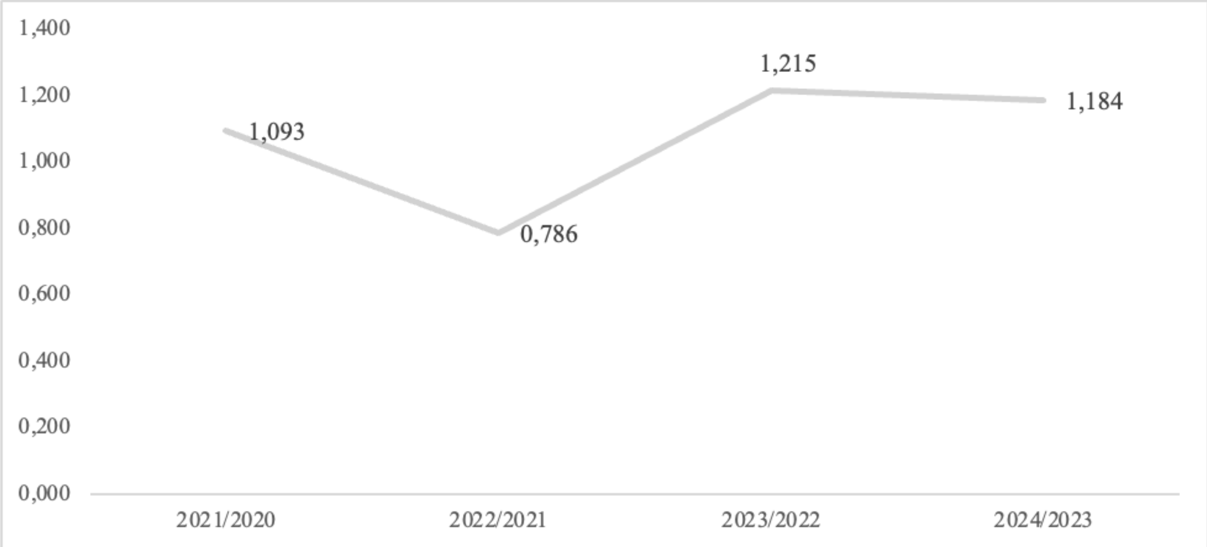

Fig. 2. Trend in the index of current investment in environmental protection, relative units [11]

Ambiguous trends were observed in the volume of current investment in environmental protection over the period under review, with periods of growth alternating with periods of decline. The sharpest drop in this indicator occurred in 2022.

A selection of local environmental indicators was carried out to assess the development and use of geo-ecological monitoring of transport infrastructure land restoration:

– conducting a financial assessment of the implementation of climate change adaptation measures ($RTIL^1_{21}$);

– index of changes in the ratio of treated to generated waste by region ($RTIL^1_{22}$);

– index of changes in generated waste relative to regional area ($RTIL^1_{23}$);

– index of changes in emissions of pollutants and carbon dioxide into the atmosphere ($RTIL^1_{24}$);

– index of changes in capital investment in environmental protection ($RTIL^1_{25}$);

– index of changes in current investment in environmental protection ($RTIL^1_{26}$);

– level of application of geographic information systems in the environmental monitoring system ($RTIL^1_{27}$);

– levels of preservation of the climate system in a state that prevents an increase in risks to human health and well-being and the natural environment ($RTIL^1_{28}$);

– Ukraine's achievement of the Sustainable Development Goals (SDGs) adopted at the United Nations Sustainable Development Summit in 2015 ($RTIL^1_{29}$);

– promoting balanced (sustainable) development by achieving a balance between the components of development (economic, environmental, social) and focusing on the priorities of balanced (sustainable) development ($RTIL^1_{210}$);

– integrating environmental requirements during the drafting and approval of national planning documents, as well as sectoral, regional and local development documents, and in the decision-making process regarding the implementation of planned activities at facilities that may have a significant impact on the environment ($RTIL^1_{211}$);

– fostering cross-sectoral partnerships and engaging stakeholders ($RTIL^1_{212}$);

– ensuring environmental safety and maintaining ecological balance within Ukraine, and improving environmental safety levels in the exclusion zone ($RTIL^1_{213}$);

– ensuring the inevitability of liability for breaches of environmental legislation ($RTIL^1_{214}$);

– improving the system of natural resource registers and state statistical reporting on the use of natural resources and environmental pollution ($RTIL^1_{215}$);

– stimulating the development of waste management infrastructure ($RTIL^1_{216}$);

– stimulating the renewal of worn-out fixed assets in industrial and transport infrastructure and housing and communal services facilities through direct state subsidies, cheaper loans, partial compensation of interest rates on loans, etc. ($RTIL^1_{217}$);

– introducing environmental accounting to assess the effectiveness of policy and management ($RTIL^1_{218}$).

Conclusions. Thus, the environmental factors influencing the development of geo-ecological monitoring of land restoration for transport infrastructure have been identified. This enables the construction of a multi-level system of indicators, the development of an assessment method, and the establishment of a quantitative basis for informed decision-making.

The identified factors make it possible to determine attribute information for geoinformation and mathematical modelling, forecasting changes, and developing technology for establishing geo-ecological monitoring of the restoration of transport infrastructure land.

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