

**CONCEPTUAL APPROACH TO MINIMALIZATION
OF ENVIRONMENTAL HAZARD
FOR THE POKUTSKO-BUKOVINIAN CARPATHIANS**

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Abstract. The existing conceptual approaches to assessment of the environmental security of the Eastern Carpathians have been analyzed. The original vision of the mechanism for maintaining sustainable development in the Pokutsko-Bukovinian Carpathians mountain ecosystem is proposed. The methodological approach used to determine the ecological status and the level of environmental safety of mountain areas is based on the use of sanitary-ecological indicators as sensitive determiners of environmental changes under the influence of the anthropogenic factor. For comparison of changes in the mountain ecosystem, the territories of the nature reserve of the mountain region were used as a standard. A system of engineering and management solutions aimed at minimizing environmental hazards in the study area has been developed.

Key words: ecological safety, mountain ecosystem, environmental indicators, engineering solutions, sustainable development.

1. Introduction

Among the basic principles of state environmental policy, reflected in the Law of Ukraine “On the Basic Principles (Strategy) of State Environmental Policy of Ukraine for the Period up to 2030” is insurance of environmental safety and maintenance of ecological balance in the territory of Ukraine [1, 2]. According to the analysis of the document, this can be achieved by refocusing on sustainable development priorities, which involves the analysis and forecasting of environmental risks based on strategic environmental assessment, environmental impact assessment, as well as comprehensive environmental monitoring.

The works of Adamenko O. M., Arkhipova L. M., Goloyad B. J., Golubets M. A., Rudko G. I., Shmandiy V. M. etc. are devoted to the issues of environmental safety of natural ecosystems, including the territorial geological complexes of the Eastern Carpathians, [3–7].

Environmental safety and sustainable development of the Carpathians, preservation of forest ecosystems, formation of the ecological network as a natural frame of environmental safety were reflected in the works of Movchan Y. I., Prykhodko M. M., Solodky V. D., Shelyag-Sosonko Yu. R. etc. [8–11].

The selection of test objects for the assessment of the state of mountain ecosystems and the formation of a methodological approach were based on the research of Gvozdnyak P. I., Mudrak O. V., Patika V. P., Rylsky A. F., Chizhevsky A. L., Gustavs K., Pall E., Sumampouw O. J. etc. [12–19].

A theoretical search has revealed that existing approaches to ensuring the environmental safety of mountain areas are not always based on the ecosystem approach; they do not use natural reserves of the protected areas as a benchmark for comparing anthropogenic impact and do not take into account the population health indicators as pointers of the status of mountain ecosystems; sanitary and microbiological indicators are still insufficiently used to assess the level of the environmental safety.

2. Methodology and research methods

We have researched the Pokutsko-Bukovinian Carpathians – a region of the Eastern Carpathians specific in terms of landscape, climate, socio-economic conditions, insufficiently studied in the aspect of environmental safety (Fig. 1). It is the outer lane of the Ukrainian

(Eastern) Carpathians within the Ivano-Frankivsk and Chernivtsi regions, extending from the Northwest to the Southeast to the Romanian border for nearly 75 km.

Despite the similarity in the whole Carpathian mountain area, the Pokutsko-Bukovinian Carpathians are characterized by specific features that determine the level of environmental safety of the given region: relief features, a large percentage (15–18 %) is occupied by mountain meadows, a lot of mountain meadows, hayfields, pastures, farmland, a sufficiently high degree of plowed land, the area is densely populated, the climate is cool and humid (up to 1000 mm of rainfall per year)

As a standard, in order to compare the impact of anthropogenic activity on the state of mountain ecosystems, we have selected protected areas located in

the Pokutsko-Bukovinian Carpathians, in particular Vizhnitskyi National Nature Park (NNP), where a specific ecosystem connected with the nature protection regime has been formed for more than two decades.

Our methodological approach to determining the ecological status and level of environmental safety of mountain areas is based on the use of sanitary and environmental indicators as sensitive pointers of environmental changes under the influence of the anthropogenic factor. It differs from the existing ones because the territories of the nature reserve fund of the mountain region are used as a standard, where due to the nature protection status, specific conditions for the development of ecosystems have been formed for ten years.



Fig. 1. Pokutsko-Bukovinian Carpathians on the map of Ukraine

3. Results and discussion

We propose a conceptual hypothesis of environmental safety of the mountain ecosystem (Fig. 2), which is based on the interaction of the following main components: rational forest management, conservation of landscape and biotic diversity, balanced use of local minerals,

sanitary-ecological state of hydrosphere, atmosphere, soil and population health.

Components 1, 2, 3 and 8 fully determine the appropriate regulatory and management measures, so they were not the focus of our research. We have limited ourselves to developing recommendations on the feasibility of the implementation of these measures,

which is a function of the authorities. Component 7 – the state of population health – is at the same time a necessary component of the environmental safety of the studied region and a decisive indicator of the effectiveness of implementation of measures to minimize environmental hazards concerning other components, shown in Fig. 2. Therefore, we use it as an integral indicator characterizing the state of ecological danger of the mountain ecosystems of the Pokutsko-Bukovynian Carpathians and the dynamics of its changes. Component 5 – the sanitary-ecological state of the atmosphere for the mountain ecosystem conditions of the Pokutsko-Bukovynian Carpathians – is not significantly anthropogenic. Therefore, we have not

considered the component, the environmental status of which needs to be improved through management or engineering activities. The environmental health of the atmosphere, as well as component 7 – the state of population health – was used as an integral indicator characterizing the state of environmental hazard to the mountain ecosystems of the Pokutsko-Bukovynian Carpathians. We have considered in detail, from the point of view of minimizing environmental hazard (which ultimately determines the state of environmental safety of the mountain ecosystems of the Pokutsko-Bukovynian Carpathians) components 4 – sanitary-ecological state of the hydrosphere, and 6 – sanitary-ecological state of the soils.

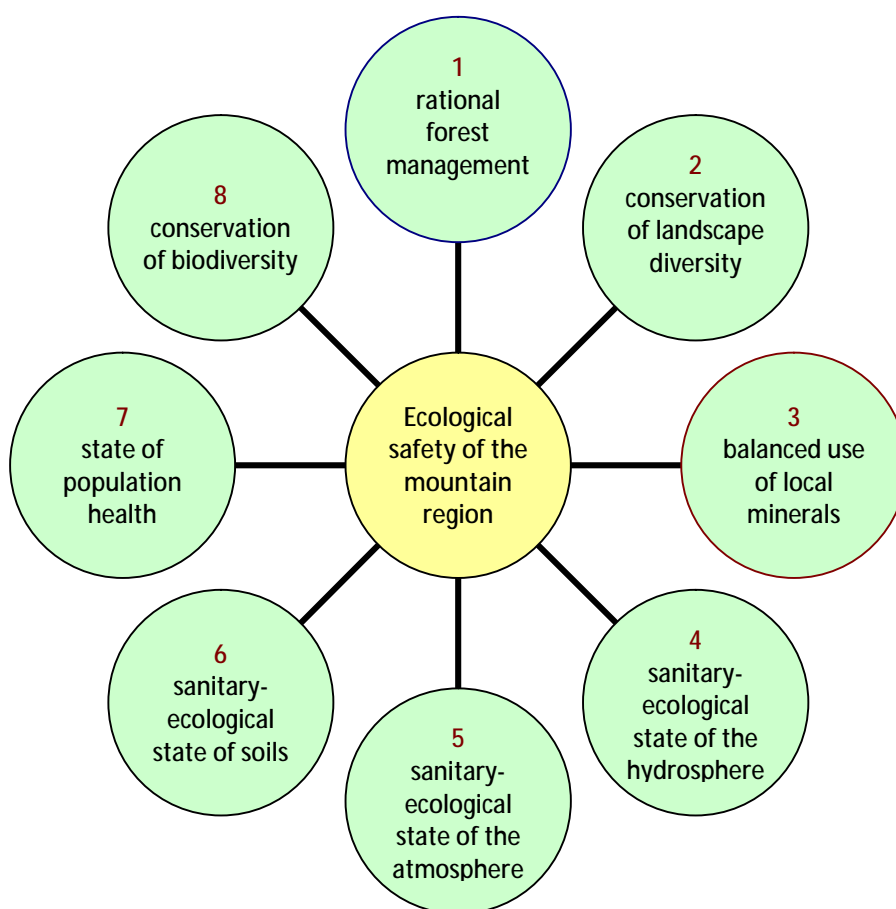


Fig. 2. Conceptual diagram of the environmental safety of a mountainous region

Theoretical and experimental studies were carried out in accordance with our proposed logical-sequential scheme, which is presented in Fig. 3. This scheme consists of three main blocks. The first is the monitoring of the state of mountain ecosystems of the Pokutsko-Bukovynian Carpathians, which contains 2 sub-blocks: the actual monitoring of the state of ecosystems and the identification of the main sources of environmental

hazard to the mountain ecosystems of the Pokutsko-Bukovynian Carpathians. In the process of monitoring of the ecosystems of the Pokutsko-Bukovynian Carpathians, we analyzed the status of protected areas, hydrosphere, atmosphere, soils, and public health. The monitoring of hydrosphere and soil contamination was crucial. We considered the conservation status of protected areas from the point of view of using information as background to

analyze the dynamics of ecosystem pollution. Population health was viewed as an integral indicator of the environmental safety of the Pokutsko-Bukovinian Carpathian ecosystem.

The initial information of the first sub-block was the input for the second sub-block - identification of the main sources of environmental hazard to ecosystems of the Pokutsko-Bukovinian Carpathians.

As a result of this identification, the environmental hazard was identified for component 4 of the environmental safety of the mountain region (Fig. 2) – the sanitary-ecological state of the hydrosphere and component 6 – the sanitary-ecological condition of the soils. Regarding component 4, two types of environmental threats were identified: microbiological contamination of streams and watercourses and pollution of the hydrosphere by the enterprises of the processing industry, which is widespread in the studied region.

The second block of the logical and theoretical scheme of theoretical and experimental dissertation studies contained a system of engineering measures to minimize the environmental hazard of the components under study.

To prevent the microbiological contamination of streams and watercourses, we used a fibrous carrier of "VIE" (TU (995990) type made of textured harness (TU 6-06-C1 16-87, tex. 350). On the fibrous carrier, a specific "biofilter" is formed in the form of an artificially created micro-ecosystem. In the microecosystem under study, the fibrous carrier serves as a kind of home for microorganisms, plant and invertebrate organisms, where they can accumulate, which is the basis of the purification of reservoirs. Besides, some bacteria become part of the food chain and serve as food for invertebrates. Thus, there is a purification of reservoirs in two stages: due to adsorption on a synthetic carrier in the first stage and trophic chains in the second.

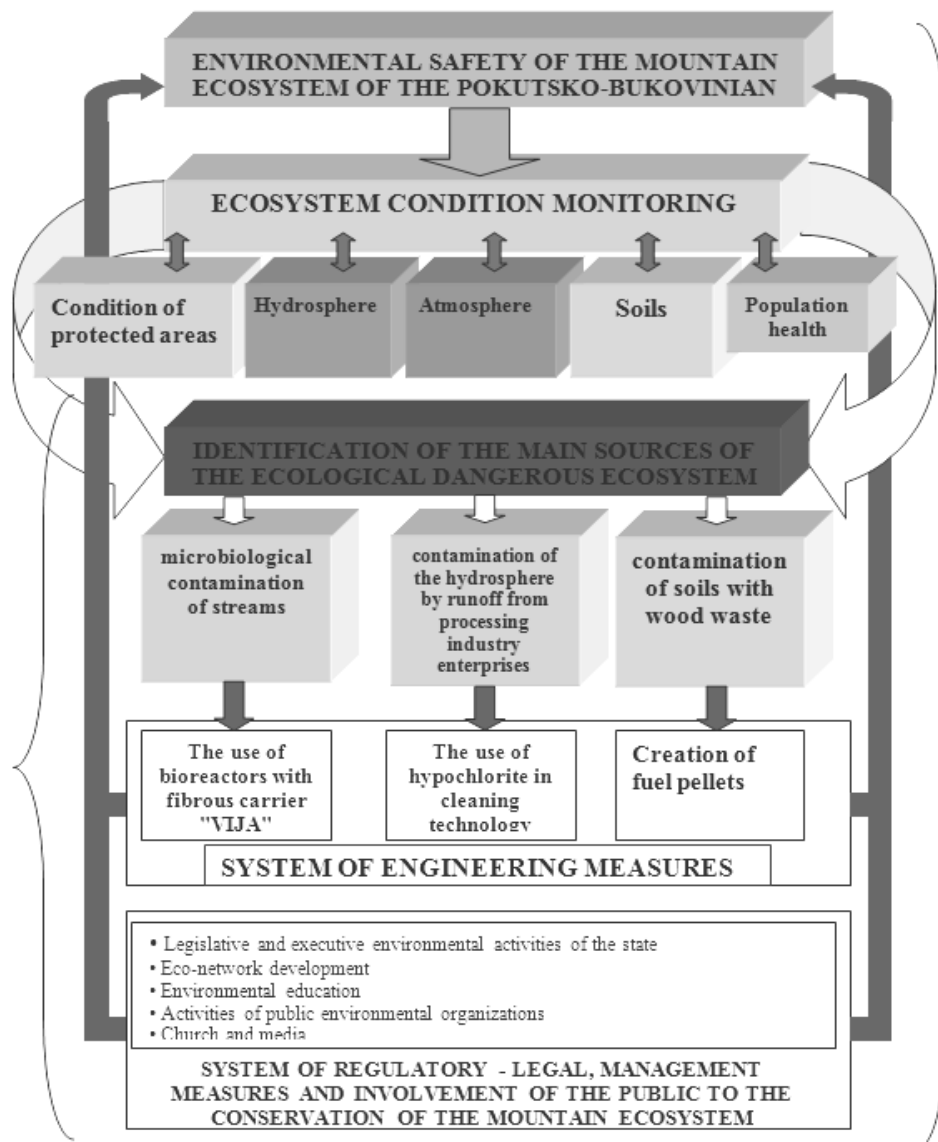


Fig. 3. Logical and sequential scheme of theoretical and experimental dissertation research

To minimize the environmental risk of contamination of the hydrosphere by runoff processing enterprises a reagent method of contamination (use of sodium hypochlorite solution) was used, which is effective, reliable and allows to provide the required degree of purification.

Soil contamination with wood waste was investigated, and fuel granule production technology was studied to prevent pollution of the soil. This technology not only prevents pollution but also allows obtaining renewable energy sources - granular biomass which reduces the environmental hazard from the use of fuel in the region, thereby reducing the environmental risk of atmospheric pollution.

The third block envisages the development of recommendations on the use of regulatory and management measures to minimize the environmental risk of all shown in Fig. 2 components of environmental safety of the ecosystems of Pokutsko-Bukovynian Carpathians.

The human health and social and economic status of the region largely depend on the ecological status of the Pokutsko-Bukovynian Carpathians. As a result of storm processes, economic activities (clogging and blockage of river beds, canals, ditches, deforestation, etc.) erosion of river banks, mudsling of water bodies occur, causing flooding and wetting of territories, damage to engineering infrastructures and communications, environmental degradation and the hydrological status of the watercourses. The result of ecologically dangerous economic activity of the population of the Pokutsko-Bukovynian Carpathians is the construction within the water protection zones, pollution of surface runoff, which gets into the river beds, residual mineral fertilizers, not absorbed by agricultural plants, etc.

Improper forestry technology and techniques have led to a number of environmental impacts, including increased average depth (> 5 %), the area of damage to the surface and volume of soil removed and washed away, increased runoff (> 50 %), more than 30 times increased water turbidity, increased areas of destroyed undergrowth and increased duration of natural recovery. Disturbance of ecological balance due to deforestation and juniper thickets in the meadows has led to the disappearance of numerous species of plants and animals, as well as to the spread of such geomorphologic processes (plane washing of soils, storm flows, landslides, floods, etc.).

The structural-logical approach used in the research has made it possible to identify major threats and challenges for the investigated mountain ecosystem (Table 1). In most cases, the territories of the mountain settlements are not provided with gas supply, which entails the use of a large amount of firewood for domestic purposes. In rural settlements, there is no infrastructure for garbage collection, which causes pollution of mountain years and streams. A significant amount of wood is added to household waste discharged into drains: sawdust and bark from private sawmills, the amount of which has increased 5–6 times in recent years. Economic activity of the population, lack of rational (environmentally friendly) use of resources, and other detrimental effects adversely affect ecosystems. Unemployment and the deepening of the social crisis in rural mountain areas are the reason for the uncontrolled use of natural resources. Due to intensive livestock grazing, the belt of the upper border of the forest undergoes significant losses, which plays an important environmental function.

Table 1

The main challenges to environmental security and their consequences for the Pokutsko-Bukovynian Carpathians

№	Name of risks and challenges implications	Effects
1.	Solid logging	<ul style="list-style-type: none"> • destruction of the hydrological grid of slopes • slope erosion and landslides • increasing frequency of floods • contamination of watercourses by forestry residues • impoverishment of the species composition of flora and fauna • reduction of the gas flow surface
2.	Physico-mechanical contamination of watercourses with wood waste and household discharges	<ul style="list-style-type: none"> • artificial barriers on rivers • activation of decay processes • deterioration of organoleptic characteristics of water
3.	Chemical contamination of watercourses by runoff from fields, meadows and livestock farms	<ul style="list-style-type: none"> • reduction of oxygen content in water • deterioration of sanitary and hygienic parameters of water
4.	The ill-conceived construction of miniges	<ul style="list-style-type: none"> • the creation of artificial barriers to the migration of aquatic organisms • reduction of biodiversity and disruption of the landscape • reduction of groundwater level
5.	Selection of gravel and sand in the river beds year	<ul style="list-style-type: none"> • change of river beds • reduction of groundwater level • violation of the integrity of the aquatic ecosystem
6.	Insufficient development of social and health services	<ul style="list-style-type: none"> • excessive use of natural resources • the destruction of mountain ecosystems • increasing morbidity

In the process of disrupting the sustainability of mountain forest ecosystems, the economy suffers significant losses, landscape and biological diversity are disrupted. The main threats to the forest ecosystems of the region are: burning of dry vegetation in the spring, breach of harvesting and logging technology, drying of fir forests in mountain areas, unauthorized felling. Chemical (acid rain), physical (industrial emissions), noise and electromagnetic pollution of the environment, chemical pollution of waterways by industrial, household and agricultural farms causes significant damage to the gene pool of biological species. An obstacle to the natural settlement of flora and fauna species is the extensive network of roads for various purposes, excessive plowing in some areas. These challenges are universal for the whole Carpathian region. Our studies have shown that anthropogenic activity has created a number of risks and challenges for mountain ecosystems in the Eastern Carpathians, which nowadays exceed the economic capacity of the biosphere. In order to reduce the level of environmental hazard from these threats, a system of engineering and management solutions was developed. Engineering solutions include the development of surface water treatment technologies, sewage treatment plants and soil cover.

The use of a ViCa (a “biofilter”) treatment structure mounted based on wooden structures and a fibrous carrier of the VIA type (TU (995990) made of textured harness (TU 6-06-C116-87, Tex. 350) made it possible to achieve a significant result [20, 21]. The advantage of the “biofilter” is its ability to accumulate suspended solids of organic nature, micro-organisms,

and invertebrates on its surface and form the artificial nutrient chain.

The combination of producers, consumers of different order and reducers in this chain, creates conditions for the flow of biogeochemical circulation of matter and energy. The result is a balanced micro-ecosystem that does not require regeneration of the “biofilter” and provides for the purification of surface water from organic matter and microorganisms (Table 2).

Although the Carpathian nature reserves play an important role in conserving biological and landscape diversity, their areas are scarce and conservation regimes are too soft. Substantial territories of the object nature reserve fund (NRF) are not decommissioned; in most cases the boundaries are not isolated in nature, which has recently been the cause of frequent land disputes between NRF administrations and local governments. A significant percentage of the NRF territories consist of landscape regional parks lacking administrative staff and, accordingly, adequate care and protection.

The lack of organized and equipped tourist routes with a rather intense tourist load causes not only the clogging of territories but also leads to the additional destruction of rare species of plants and animals. Hunting for game and fish (especially trout) is quite characteristic of the mountain area. The number of hunters is increasing; there is falsification of game records and, as a result, competition between hunters and predators. On the other hand, the reduction of natural hunting objects in some cases leads to attacks by predators on livestock, which causes a confrontation between the latter and the farmers.

Table 2

**Efficiency of of “biofilters” functioning under conditions of surface water pollution
in the economic zone of NPP “Vizhnitsky”**

№	Indicators	Economic zone		
		to “biofilter”	after “biofilter”	± B %
1.	hygiene indicators			
1.1	suspended matter (g / dm ³)	3.63 ± 0.12	2.80± 0.10	-23.9
1.2	dissolved oxygen (mg O ₂ / dm ³)	4.00 ± 0.22	5.32± 0.25	+33.0
1.3	chlorides (mg/ dm ³)	0.83 ± 0.04	0.40± 0. 02	- 51.9
1.4	nitrite (mg/мл)	0.13 ± 0.011	0.05	- 61.5
1.5	BOC ₅ (mg O ₂ / dm ³)	7.57 ± 0.45	5.3± 0.20	-30.0
1.6	COC (mg O ₂ /dm ³)	25.30 ± 1.17	17.9	- 29.3
2.	microbiological indicators			
2.1	coli-index	111.7 ± 5.4	96.0± 4.5	-14.1
2.2	coli-titer	7.4 ± 0.33	6.6 ± 0.25	- 10.9
2.3	total microbial number (CFO/dm ³)	5350 ± 270	4800 ± 205	- 10.3

This results in a balanced micro-ecosystem that does not require regeneration “biofilter” and provides clean surface water from organic substances and microorganisms (Table 2).

According to the data in Table 2, the “biofilter” promotes the purification of surface waters from the suspended matter and their saturation with dissolved oxygen, as evidenced by the BOC5 and COC. Besides, the number of bacterial organisms significantly decreases in watercourses.

A technology based on the reagent method using sodium hypochlorite has been developed for the treatment of effluents from processing plants [22].

For the oxidation of organic compounds, we used the most affordable, cheapest and safest sodium hypochlorite reagent, a multi-tonne waste of metallic sodium production (located in Kalush). In the process of research, it was possible to achieve the necessary degree of sewage treatment, which allows in practice to discharge sewage into reservoirs after its purification by the specified method. The proposed technology has several advantages, namely:

- low cost of reagent supply;
- an available reagent (sodium hypochlorite) is used;
- low reagent costs, low amount of waste generated (only oxidized, disinfected organic pollutants);

- the possibility of using the technology after a slight upgrade of the existing treatment facilities

- the possibility of using waste as an effective organo-mineral fertilizer.

In the system of engineering solutions aimed at reducing soil contamination by forestry waste and wood processing industry, we have developed advanced technology for the production of fuel pellets and briquettes [23, 24]. A feature of this technology is the use of “sulfate soap” as a binder component - the lignin-containing waste produced by Zhydachiv pulp and paper mill. The most appropriate binder concentration for extrusion molding is 20 %. With this concentration of the binder component, the calorific value of the pellets was increased by 38 % compared to wood waste. When molding briquettes by the method of pressing, the addition of a binder allowed increasing the static strength of briquettes and their calorific value by 20 %. At the same time, the binder serves as a lubricant which reduces the friction forces and, therefore, the energy costs to overcome them. Thus, the proposed technology includes a significant environmental component, in addition to the economic one. This applies, in particular, to the disposal of pulp and paper waste, the accumulation of which poses a serious threat to the environment (Fig. 5).

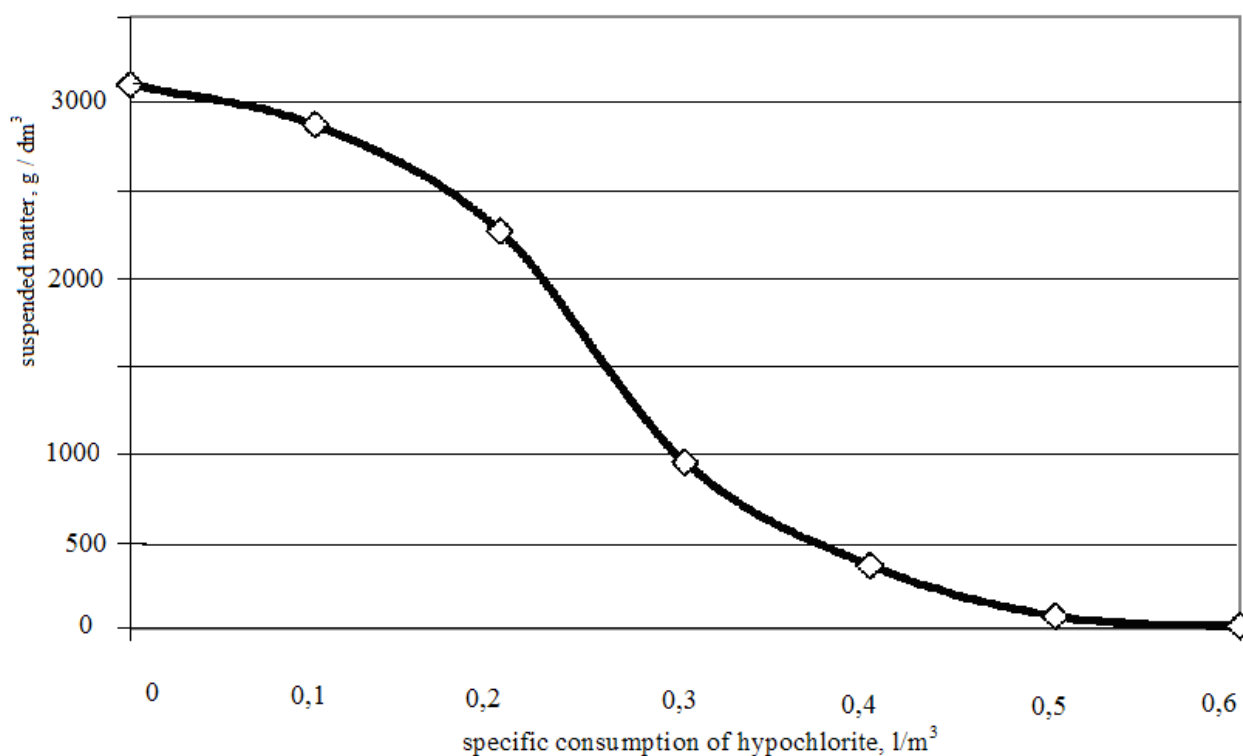


Fig. 4. Dependence of the dry matter mass on the specific consumption of hypochlorite

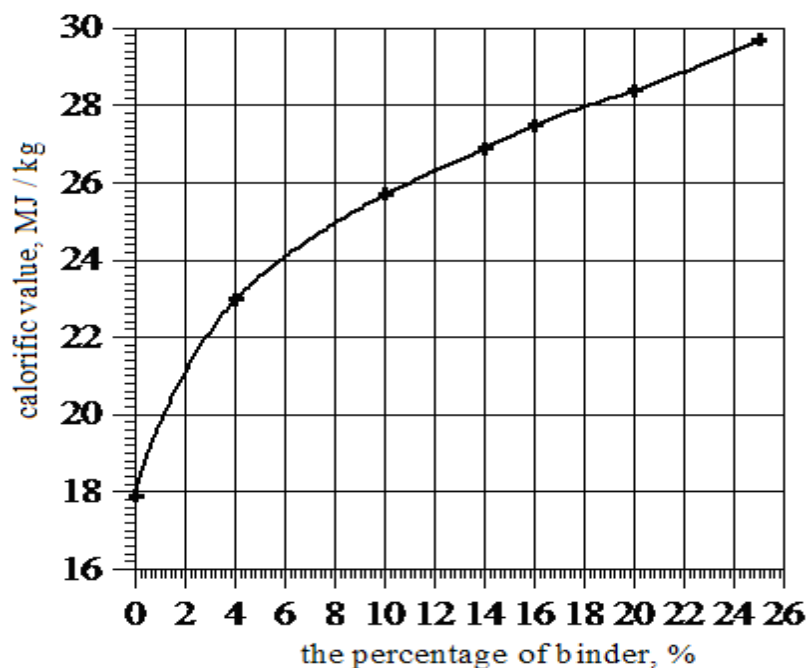


Fig. 5. The dependence of the calorific value of the granules on the percentage of a binder

Among the organizational and management decisions, in our opinion, the following measures can be aimed at:

- expansion of the territory and removal of the boundaries of the protected object;
- development of proposals for local governments on the formation of the NPP territory on the watershed principle;
- formation of forest stands due to indigenous species of trees taking into account their phytopathological and acid resistance;
- involvement of scientists from higher education institutions of the region and public environmental organizations in the issues of nature conservation management in protected areas;
- active environmental education through the functioning of environmental education centers;
 - holding round tables, seminars, scientific conferences on climate protection, formation of regional and cross-border network;
 - expanding environmental services to the local population;
 - development of recreation taking into account anthropogenic load;
 - active involvement of funds from international grant programs in strengthening the structure and material support of NPPs.

Conclusions

The proposed methodological approach made it possible to assess the ecological status of the Pokutsko-Bukovynian Carpathian ecotope and to identify major

threats to the environmental safety of the region, taking into account the sanitary and microbiological characteristics of the region. To reduce the level of environmental hazard, a system of engineering solutions has been developed, including technologies for surface water treatment, sewage treatment of small processing plants and soils of the studied mountain ecosystem. Engineering and technical solutions are complemented by organizational and managerial measures that combine environmental activities with the socio-economic sphere and ensure the sustainable development of the Pokutsko-Bukovynian Carpathians.

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