Проведені дослідження шляхів забезпечення екологічної безпеки рекреаційних територій гірської екосистеми на прикладі національного природного парку (НПП) «Вижницький» Покутсько-Буковинських Карпат. Проаналізовано існуючі підходи забезпечення екологічної безпеки об'єктів природно-заповідного фонду. Приведена характеристика регіону досліджень. Запропонована концепція забезпечення екологічної безпеки рекреаційних територій, яка грунтується на аналізі складових та встановленні тих компонентів, покращення яких забезпечить відповідний рівень екологічної безпеки НПП. Розроблений алгоритм проведення теоретичних та експериментальних досліджень для оцінки санітарно-мікробіологічного стану атмосфери, гідросфери та грунтів в районі досліджень та їх впливу на екологічну безпеку НПП.

З ціллю аналізу стану рекреаційних територій гірської екосистеми проведений моніторинг санітарно-мікробіологічних та санітарно-екологічних показників гідросфери, атмосфери та грунтів та ідентифікація екологічних загроз. Запропоновано для забезпечення збереження лімітованих значень санітарно-мікробіологічних та санітарно-екологічних показників гідросфери планувати заходи щодо інтенсифікації біологічних природних процесів самоочищення поверхневих вод в зоні територій рекреації. Результати моніторингу атмосферного повітря в зоні територій рекреації свідчать про те, що вміст аероіонів в 2,4 рази вищий, а загальне мікробне число в 1,5 рази нижче, ніж на території традиційного господарювання. Тому атмосфера зони рекреації не потребує реалізації будь-яких технічних заходів для її покращення. Запропонована система інженерних заходів для стабілізації екологічної безпеки в зоні рекреаційних територій (використання волокнистого носія «Вія») для інтенсифікації очищення поверхневих водойм та утилізація деревних відходів шляхом виготовлення біопалива).

Впровадження запропонованих заходів допоможе добитись стабілізації екологічної безпеки рекреаційних територій гірської екосистеми

Ключові слова: екологічна безпека, рекреаційні території, санітарно-мікробіологічні показники, санітарно-екологічні показники, моніторинг, гідросфера

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ANALYSIS OF ENVIRONMENTAL SAFETY OF RECREATIONAL TERRITORIES OF MOUNTAIN ECOSYSTEMS AND DEVELOPMENT OF TECHNICAL MEASURES FOR ITS STABILIZATION

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1. Introduction

One of the functions of national nature parks, in addition to preservation and restoration of landscape and biodiversity, is to provide opportunities for recreation and health improvement for the population. One should note that the mentioned sphere of services has a strong economic basis for the development of nature reserve objects. At the same time, an increase in anthropogenic pressure accompanies the development of recreation on nature reserve areas. Unreasonable development of recreation in these territories leads to disturbance of environmental balance. It causes a breakdown of environmental and technogenic safety of the region (excessive contamination of soil and watercourses, disturbance of landscapes and destruction of flora and fauna, occurrence of fires, etc.).

The threat to the environmental safety of the region became acute in the mountainous part of the Ukrainian Carpathians in recent years due to the anthropogenic influence. The registered heavy floods in the Ukrainian part of the Danube basin at the end of the XX beginning of the XXI century confirm the fact clearly.

Recreational territories are at risk due to the effect of anthropogenic activity [1, 2] and pollution by the waste of neighboring residential areas [3, 4] regardless of their location. The Pokutsko-Bukovynian Carpathians have environmental problems, which are typical for the whole Carpathian region. However, they have their specificity due to transboundary conditions, peculiarities of climatic conditions, traditional farming, etc. There is destruction of mountain landscapes, destruction of biodiversity and erosion of soil cover due to irrational forestry, plowing and cutting of slopes, construction of roads, grazing of livestock, etc. One also observes periodic floods. Mountain ecosystems became rather vulnerable due to human economic activity. They require, if not complete protection, at least careful attitude and balanced use. Therefore, it is necessary to analyze and forecast ways of balanced development in the face of modern challenges, in order to implement the main regulations of the Carpathian Convention and to create environmentally safe conditions in the region.

Sanitary-hygienic and microbiological indicators can be quite promising for assessment of the environmental status of recreational territories and for forecasting of recreational load. They are still underutilized for these purposes.

That is why the substantiation of the necessity to comply with environmental safety requirements in the development of recreational territories of nature reserve objects is a relevant task. We analyzed and investigated it in this study.

2. Literature review and problem statement

The most universal nature reserve stock facilities for recreational activity are national nature parks (NNPs). NNP provides a universal ratio of different activities and corresponding functional zones. Creation of four functional zones in NPP territories is usual in the world practice and in Ukraine. The zones are:

1) protected zone;
2) regulated recreation zone;
3) stationary recreation zone;
4) economic zone.

There are individual modes of protection and use of natural resources for each of the zones according to their features. All economic activities of a NNP take place in accordance with zone modes.

The territory of the protected zone has the strictest mode of protection. It is intended to preserve the most valuable natural-territorial complexes. It is possible to have a short rest on the territory of the regulated recreation area, but it is forbidden to cut down forests, all kinds of industrial fishing and any other form of activity, which may affect the condition of the territory and objects of the area negatively. There may be hotels, campsites, motels in a stationary recreation area, but it any activity, which that is not targeted to the area or can cause environmental damage, is forbidden. An economic area is intended for economic activity in accordance with the purpose of an NNP [5].

Authors of papers [6, 7] present the results of studies, which show that some NNPs (Carpathian NNP, Shatsky NNP, Holy Mountain NNP) are undergoing a significant recreational load. But the issues of optimal recreational load for newly established parks remain unresolved. The reasons may be a short functioning period of these parks and an insufficient degree of study of the impact of recreational load on the environment of an NNP.

Researchers [8, 9] state that the environmental state of recreational zones of the Carpathian National Nature Park is at considerable risk due to an increased impact of recreational activities. The degradation of territories due to recreational activity has a wide range of manifestations within the paths of environmental trails to Hoverla Mountain. They include trampling of grass and forest floor, erosion processes on slopes, damage to bushes and trees, littering of territories. The created noise load scares animals and birds. Access roads are a particular danger. Motor transport causes formation of geochemical anomalies with a high content of heavy metals along roads.

Broadening of access roads causes formation of landslides, sloughs and landslips. However, a number of issues related to the impact of anthropogenic changes on Carpathian vegetation remain unresolved. Publication [8] investigates the results of the analysis of the anatomical structure of leaf blades of narrow-leaved fescue grass on the example of *Festuca valesiaca agg.* (*Poaceae*) populations. There is a study in the same perspective in publication [9]. It reports results of the studies on recreational digression by indicators of change in microrelief. However, the mentioned studies refer to the conditions of the Carpathian NNP only. One cannot apply them to all NNPs with different conditions.

Work [10] shows the degradation role of anthropogenic load in the occurrence of recreational digression in the territory of Shatsky NNP. Authors carried out studies in the area of stationary and regulated recreation. The obtained results show that the existing recreational activity plan does not make possible recovering of natural components of the park. The issue of the analysis of causes of recreational digression on the territory of Shatsky National Park remains unresolved. Authors of paper [11] state that the cause is functioning of the Hotislavsky Quarry, which is close to Shatsky NNP. Its activity leads to a reduction in the surface runoff of rivers, a decrease in the reach of local lakes, which may lead to disappearance of a number of populations of The Red Book plants and animals in future. Therefore, we need profound studies on the impact of economic activity on the state of NNPs.

Authors of a work [12] investigate an influence of recreational-and-tourist complexes located in the area of stationary recreation on the river water quality on the example of "Zacharovanniy kray" NNP. They registered the exceeding of the biological oxygen consumption indicator at the level of 1.6–2.6 values of maximum permissible concentration, which indicates organic pollution. A decrease of the indicator during periods of a decrease in the number of recreants only confirms the negative influence of recreants on functional areas of protected territories.

Studies [13] established the destructive impact of recreation on the protected territories of "Kinburnska Kosa" regional landscape park and the adjacent "Svyatoslav's Biloberezhya" NNP. The sites are located within the Kinburn Peninsula. It is possible to resolve the problem by approval of the distribution of park areas, which will prevent exceeding of recreation rates and reduce the risk of poaching. It is expedient to introduce zoning in "Vizhnytsky" NNP. The preliminary stage of zoning is environmental monitoring. The mentioned studies investigate it.

Studies in paper [14] show a connection between increasing recreational load on a landscape and a degree of its degradation on the example of "Ojcow National Park" and "Tatrzhansky National Park" of Poland and the English national parks, such as 'The lake Dictrict" and "Exmoor". The degradation occurred mainly due to a significant increase in visitor traffic. As a consequence, construction of highways, an impact of road transport, an increase in a number of hotel buildings, etc., put representative properties of the national parks on the edge of existence. This fact reaffirms a need for regulation of recreation and zoning of NNPs based on environmental monitoring data.

Studies [15, 16] consider changes in the environmental state of soil and plant environment of recreational areas. There is a decrease in the resistance of plants to various types of diseases and differences of herbaceous species composition from undisturbed forest in places for recreation. Consequently, there is reduction of biomass of litter, soil compaction, a change of air permeability and moisture permeability of soil. Therefore, there is a need for a thorough study of a change in the soil environment in NNP, which is part of the studies below.

Author of work [17] present typification of negative impacts on the environmental state of recreational zones. There are following typical impacts on recreational areas of protected areas: soil erosion and compaction, damage to plants, water pollution, increased frequency of fires, vandalism and noise. The author proposes various means of minimization of negative impacts. They include encouraging to choose leisure activities with a low negative impact. This aspect requires further investigation under conditions of "Vizhnytsky" NNP.

Author of study [18] analyzes negative effects of tourism on the state of the most common national parks in the United States. Along with the common typical problems outlined above, there is increasing damage to the animal world. For example, the excessive use of snowmobiles in winter at the Yellowstone National Park and aircraft in the Grand Canyon National Park created an excessive noise load, which reduced populations of the most sensitive birds. Therefore, there were significant restrictions imposed on the use of snowmobiles and aircraft. It is expedient to apply such measures to ensure preservation of environmental standards in "Vizhnytsky" NNP.

Researchers analyzed the environmental state of protected recreational territories under a negative impact of mountain and equestrian recreational services on the territory of Australia's mountain reserves [19]. The identified major problems include significant trampling of the territory and alteration of the grass cover and water pollution as a result. At the same time, atmospheric air pollution is insignificant, which correlates with our studies entirely. There are results of our studies summarized below.

Authors of work [20] investigated the environmental state of recreation in the territory of national parks of Russia. They found significant changes in the soil cover on 80–90 % of popular recreational routes. However, there were no statistically high correlation between a number of recreants and the extent of damage to forests. Researchers found a decrease in ability of forest ecosystems to restore and a significant reduction in species diversity in recreation zones in paper [21]. In addition, they registered a sharp decrease in grass cover from 86 % to 8.9 % with the predominance of weed species in recreation zones. One needs further studies to establish a correlation between environmental state and recreational load.

Studies [22, 23] considered assessment of the impact of recreational activity on preservation of particularly valuable protected territories. They emphasized the role of continuous monitoring of the environment in recreation zones. They stated that, provided that their condition stabilizes, recreational activities can be one of the important components of filling of budgets, especially for regions, which are poor in other types of resources.

The general tendency in minimization of the impact of anthropogenic activity on NNPs is the use of renewable energy sources [24] to prevent pollution of the hydrosphere. The sources are natural sorbents [25], membrane methods [26] and biological natural purification methods [27].

Thus, our analysis of the environmental state of recreational zones of protected areas in Ukraine, and globally, showed the presence of degrading impact of recreational activities on the state of protected territories. This kind of influence reaches critical values in presence of large numbers of recreational activities, and threatens to destroy representative properties of recreational territories. Therefore, constant control, environmental monitoring and assessment of the quality composition of protected territories are prerequisites for prevention of their degradation.

3. The aim and objectives of the study

The aim of this study was to assess a level of environmental safety of recreational territories of a mountain ecosystem on the example of "Vizhnitsky" National Nature Park of the Pokutsko-Bukovynian Carpathians.

It was necessary to resolve the following tasks to achieve the objective:

– proposition of a conceptual scheme of environmental safety of NNP recreational territories and development of an algorithm for conduction of theoretical and experimental studies;

– monitoring of sanitary-microbiological and sanitary-environmental indicators of hydrosphere, atmosphere and soils in the territory of recreational zones on the example of "Vizhnitsky" National Nature Park of the Pokutsko-Bukovynian Carpathians; to identificate threats and challenges for environmental safety of stationary and regulated zones of the object under study;

– development of a system of engineering solutions for a decrease in the level of environmental danger in recreational territories on the example of "Vizhnitsky" National Nature Park of the Pokutsko-Bukovynian Carpathians.

4. Materials and methods to study environmental safety and monitor environmental safety sources

4. 1. Methodology for the study on drying of ground wood waste

It is necessary to study the effect of a speed of the thermal agent, its temperature, thickness of a layer on the drying process of wood waste to organize the technological process of drying properly. We carried out experimental studies on the process of drying of forest waste at different material layer height and different temperature of a thermal agent.

The studies on the drying of grinded wood waste were carried out at the experimental plant. There is a detailed description of the plant in a paper [28].

4. 2. Methodology to study the formation of fuel briquettes of wood waste

Fuel briquettes were fabricated at a hydraulic press (Fig. 1). We placed a mould for formation of briquettes in the hydraulic press.

Fig. 1. Hydraulic press used to form fuel briquettes

A constant weight of wood waste and a weight of binding agent was added, which was measured according to percentage content, for pressing of a briquette. We carried out the experiments mixing components and supplying a binding agent to the center of the mold.

The heat capacity of briquettes was determined in line with the method described in work [29].

We determined the moisture content of raw materials in the drying chamber heated to a temperature of 105 °C according to the method described in paper [30]. The sample was weighed on the analytical scales and placed in the chamber. We took the samples out after equal time intervals and placed them in a desiccator for 1,800 s. We took the samples out and weighed after. The experiment was repeated until the difference between two weights was less than $1\cdot10^{-7}$ kg. One could consider the mass of the last weighing as constant after reaching the mentioned ratio, so the experiment was completed and we calculated the moisture content.

4. 3. Methodology for determining the concentration of air ions in the atmospheric air

We determined the concentration of air ions using MAC-01 portable meter of air masses (the installed mobility level was 0.4 $cm^2/V\cdot s$) according to the manual (MAC-03 device) [31]. Modern air ion meters have large relative measurement errors (40–50 %), which requires a large number of measurements to obtain reliable data. One measurement consists of determination of the average value for each polarity at 25 readings according to the MAC-01 instruction manual. A degree of ionization of the air environment was determined by a number of ions of each polarity in one cubic centimeter of air. The unipolarity indicator was calculated according to the measurement results. It is defined as a ratio of a concentration of positive air ions to the concentration of negative ones [32]:

$$U=n^+/n^-. \quad (1)$$

We used the indicators specified in the Soviet normative documents and indicators used in Russian SanPiN currently, because there are no valid sanitary standards in Ukraine in the field of normalization of air ionization indicators. Accordingly, the normalized value of this indicator was in the range of $0.4\leq U\leq 1.0$.

4. 4. Methodology for studying the microbiological and biological activity of soils

We carried out soil sampling using the method of an envelope of 5×5 m size in four times repetition. The joint sample was made by mixing five spot samples taken from a single site at a depth of 10–15 cm at a distance of 5 m from roads and forest clearings. Microorganisms were separated from soil samples; calculation for the total number was performed according to the methods described in paper [33]. We calculated the arithmetic average and the total microbial number using the sum of colonies grown on two plates of one cultivation. The results of parallel seeding from the same cultivation were summarized and the average number of colonies was determined. Results of the analysis were presented in colony forming units per 1 g of absolutely dry soil. We calculated the number of cells per 1 ml of the studied substrate by formula (2):

$$M=V\,A\,10n, \quad (2)$$

where M is the number of cells per 1 ml of suspension; A is the average number of colonies in a seeding of a cultivation, from which the seeding is made; V is the volume of suspension taken for a seeding, ml; $10n$ is a coefficient of cultivation.

We determined urease (KF 3.5.1.5) by the methods generally accepted in soil biochemistry to assess the biological activity of soils [34]. We determined total nitrogen, ammonium nitrogen and nitrate nitrogen according to DSTU ISO 14255:2005 [35].

4. 5. Methodology for determining the sanitary-hygienic indicators and chemical composition of aquatic environment

Chemical oxygen demand (COD) was determined by the dichromate method according to the technique described in paper [36]. We determined an indicator of a dissolved oxygen concentration by the Winkler iodometric titration method [37]. The indicator of biochemical oxygen demand for 5 days (BOD_5) was determined by the method described in work [38].

5. Characteristics of the Pokutsko-Bukovynian Carpathians in the area of "Vizhnitsky" NNP

We chose the Pokutsko-Bukovynian Carpathians for the study. Namely, the region of Eastern Carpathians (Fig. 2) due their specific conditions in terms of landscape, climate and social-economic conditions, which are insufficiently studied in the aspect of environmental safety. They are the outer line 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 of the Carpathian mountain country in the whole, the Pokutsko-Bukovynian Carpathians have their specific features. They determine the level of environmental safety of the region, namely, their features of the relief, a significant percentage (15–18 %) of mountain meadows, lot of grassland, hayfields, pastures, and farmlands. In addition, there is a sufficiently large part of plowed land. The area is densely populated. The climate is cool and humid (up to 1,000 mm of rainfall per year). We chose the protected zones of the nature reserve object located in the Pokutsko-Bukovynian Carpathians as a control sample for comparing the impact of anthropogenic activity on the state of mountain ecosystems. This is, in particular, "Vizhnytsky" National Nature Park. There has been a developed specific ecosystem related to environmental protection over the last two decades.

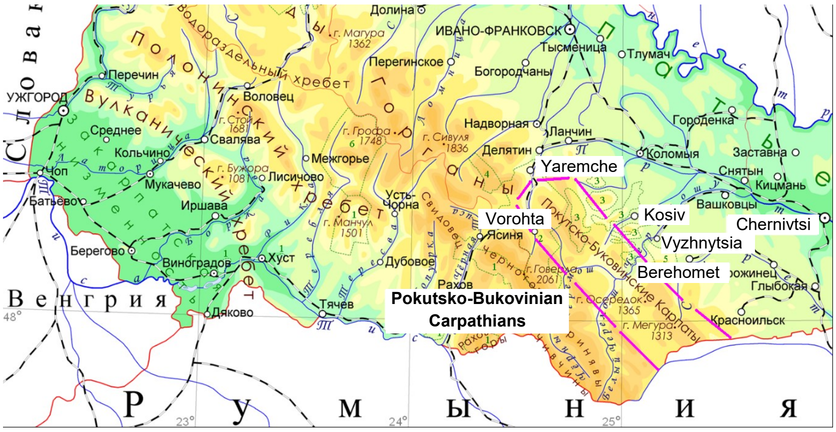

Fig. 2. Pokutsko-Bukovinsky Carpathians on the map of Ukraine

6. Results of studies on environmental safety aspects and monitoring of environmental safety sources

6. 1. Conceptual scheme of environmental safety of NNP recreational territories

We proposed the conceptual scheme (Fig. 3) of environmental safety of recreation territories based on the interaction between a number of components. They were the preservation of landscape and biotic diversity, sanitary-environmental state of the hydrosphere, atmosphere, soils and scientifically substantiated recreational load, etc. (Fig. 3).

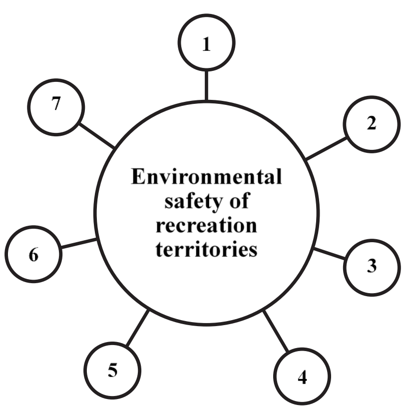

Fig. 3. Conceptual scheme of environmental safety of recreational territories: 1 — scientifically substantiated recreational load; 2 — improvement of nature protection legislation; 3 — preservation of landscapes; 4 — preservation of biodiversity; 5 — greening of economic activity around an object; 6 — an influence on environmental consciousness through mass media and religious and public organizations; 7 — sanitary-microbiological state of the hydrosphere, atmosphere and soil

A system of legal acts and organizational and management decisions provides a number of components of environmental safety of recreational territories of NPPs (1–6). Issues of assessment of a sanitary-microbiological state of the atmosphere, hydrosphere and soils are much less studied and covered in the legal and scientific bases (component 7). We proposed an algorithm of theoretical and experimental dissertation studies for assessment of a sanitary-microbiological state of the atmosphere, hydrosphere and soils and development of proposals for minimization of environmental danger of these environmental components (Fig. 4).

The algorithm consists of three main blocks. The first block is the actual monitoring of the state of the main components of the physical environment (hydrosphere, soil and atmosphere) of "Vizhnytsky" NPP stationary and regulated recreation zone. The output data of the first block (a monitoring block) provided the basis for identification of the main sources of environmental threats and challenges for the object (Unit 2).

The third block of the study algorithm contains a system of engineering and organizational-managerial measures designed to minimize the environmental danger of the studied components of the hydrosphere and soil.

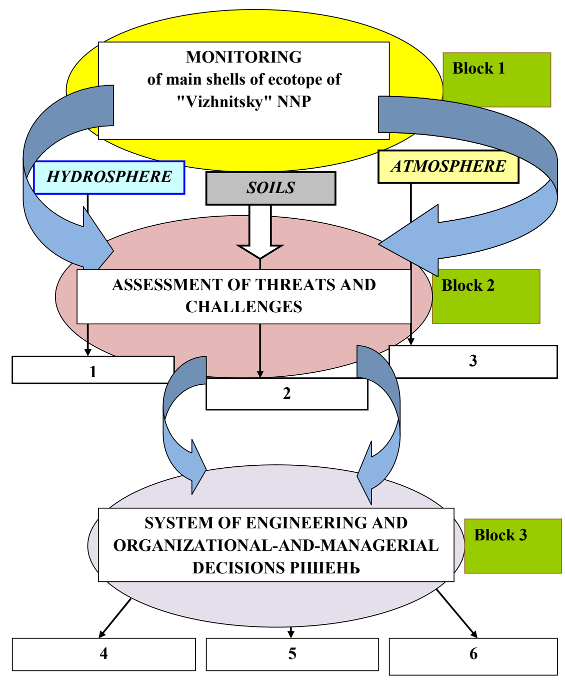

Fig. 4. Algorithm of theoretical and experimental studies: 1 — microbiological organic, mineral pollution, etc.; 2 — wood waste, livestock waste, soil erosion, mudflows, etc.; 3 — transfer of air flows from the territory of traditional economic landscapes, acid rain, etc.; 4 — creation of purifying structures based on a fibrous carrier, formation of NNP territory by the watershed principle, environmental education, etc.; 5 — waste utilization, production of fuel pellets, involvement of mass media, educational cult and public organizations, etc.; 6 — legal regulation, creation of acid-resistant, plantations, formation of indigenous forest stands, holding of round tables, excursions, etc.

6. 2. Monitoring of sanitary-microbiological and sanitary-environmental indicators of the hydrosphere

A dense network of streams, which belong to the basins of the Cheremosh and Siret rivers, covers the studied territory. Table 1 gives the main sanitary-hygienic indicators of surface water in the territory of the objects of recreation of "Vizhnitsky" NNP and in the adjacent territories of economic activity (TEA).

The decrease in the free oxygen content and the corresponding increase in BOD_5 and COD in the zone of traditional farming indicate that there is a general tendency of pollution of hydro-ecosystem due to anthropogenic activity.

We performed the analysis of monitoring data of sanitary-hygienic indicators of hydro-ecosystems of recreational areas and territories of traditional farming for the last 5 years. The results show positive changes in surface water, as evidenced by an increase in soluble oxygen content, a decrease in the content of suspended solids, and a corresponding decrease in BOD_5.

We also studied microbiological indicators of the hydrosphere in the area of recreational territories, such as coli index and total microbial number. Table 2 gives results of the studies.

The data in Table 2 prove that surface water of the recreation zone has much smaller indicator of the total microbial number, which does not exceed the SanPin norm, and therefore it is free of bacterial contamination.

Comparison of the indicators of the coli index in the river water samples of the protected zone and the selected water samples in the economic zone showed an increase in the coli index by in 2 times on average. The total microbial number (CFU/dm^3) did not exceed the normative indicators of SanPin. It was within 3000–3500 CFU/dm^3 for the zone of stationary recreation.

It is advisable to plan measures for intensification of biological natural processes of surface water self-purification in the area of recreation territories in order to stay within the limits of sanitary-microbiological and sanitary-environmental indicators of the hydrosphere.

6. 3. Monitoring of sanitary-microbiological and sanitary-environmental indicators of the atmosphere

We assessed an air ionic composition of the atmospheric air using MAC-01 air ions meter. The meter made it possible to quantify the quality of the atmospheric air in places of rest of NNP visitors despite the sufficiently high relative error.

Given that air quality is an integral indicator, which objectively reflects the environmental state of water, soil, biota, we used indicators of quality of air basin as reliable indicators of environmental safety. They describe the natural ecosystem in general.

According to the monitoring data, the quality of atmospheric air in the recreation zone over the last 5 years had an increasing trend line of observations (Fig. 5). The number of negative air ions and a value of the unipolarity indicator reflect the trend.

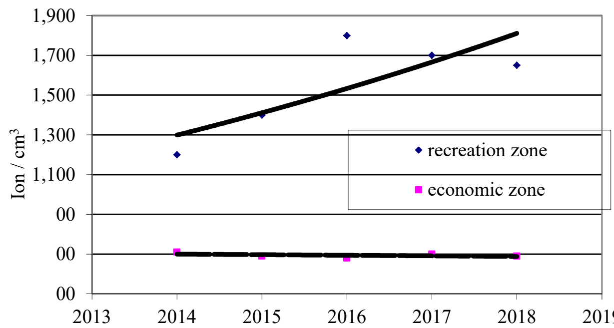

Fig. 5. Dynamics of the air ion content (ion/cm^3) in economic zones of different nature protection status

As for the comparison of indicators of the quality of atmospheric air in the NPP recreation zone and the territories of traditional farming outside the protected area (Table 3), there is a striking difference in favor of the first zone.

Table 1

Comparative analysis of sanitary-hygienic indicators of surface waters

Points of sample collection	Indicator							
	SS (mg/dm^3)	*DO* (mg O_2/dm^3)	BOD_5 (mg O_2/dm^3)	COD (mg O_2/dm^3)	*T* (°C)	pH	Chlorides (by Cl^-) mg/dm^3	Nitrites (by NO_2^-) mg/ dm^3
Average value in NNP	1.60±0.06	5.84±0.25	5.23±0.22	12.9±0.53	19	6.7	36±1.2	0.30±0.02
Average value in TEA	1.66±0.05	4.30±0.21	6.24±0.23	14.7±0.65	19	6.7	60±1.8	0.44±0.03
SanPiN 4630–88	0.75	>4.0	<6.0	<30.0	18–20	6.5–8.5	<350	<3.3

Note: SS is the content of suspended solids; DO is the content of dissolved oxygen

Table 2

Comparative analysis of sanitary-microbiological indicators of surface waters

Points of sample collection	Coli index, dm^3	Total microbial number, CFU/ml
Average value in NNP	90.9±4.0	3,019±128
Average value in TEA	112.5±6.5	6,500±310
SanPiN 4630-88	<100	<5,000

Table 3

Comparative analysis of sanitary and environmental indicators of air

No.	Indicators of the state of the atmosphere air	Average value in NNP	Average value in TEA
1	Concentration of negative light air ions, in cm^3	1,666.25	690
2	Concentration of positive light air ions, in cm^3	1,227.20	676
3	Coefficient of unipolarity (Y)	0.75	0.83

We studied the microbiological state of the atmospheric air by the generally accepted sedimentation method. A number of demonstrative microorganisms were detected in the air of the recreational zones. They were *Sarcina lutea* and *S. rosea*, *Bacillus mycoides* and *B/subtilis*, *Microbacterium candicans* and *M. flavus.* One should note that the listed species do not include representatives of pathogenic microflora.

Most of the identified representatives of the air microflora belong to chemoorganoheterotrophs. Chemoorganogeterotrophy is a type of nutrition characteristic of microorganisms, which receive required energy and carbon from organic compounds. There are aerobic and anaerobic species among these microorganisms, which live mainly in soil and other substrates. Rains and melt water wash them away. They are also evaporated into the air.

It was established (Table 4) that there was an increase in the total microbial number and species diversity of the microflora in the atmospheric air of the NNP economic zone and the zones of traditional economic landscapes located around the protected object territory. This is especially true for the zone of traditional landscapes. However, one should note that the detected strains of microflora in these areas are harmless to the human body or belong to a group of conditionally pathogenic.

Table 4

Comparative analysis of sanitary-microbiological indicators of the atmospheric air

No.	Sanitary-microbiological indicators of the atmospheric air	Average value in NNP	Average value in TEA
1	Total microbial number, q-ty in m^3	177.45±15.2	265.00±12.4
2	Number of detected species of microflora	3–4	3–4

Thus, the results of the atmospheric air monitoring in the zone of recreation territories indicate its high quality indicators. They do not require any technical measures to improve them.

6. 4. Monitoring of sanitary-hygienic indicators of soils in the territory of recreational zones of "Vizhnitsky" NNP and identification of environmental threats

We studied the sanitary-hygienic state of soils based on the analysis of indicators of interchanges in various forms of nitrogen (in particular, ammonium and nitrate forms). An active role in this process belongs to the enzyme urease, which controls the process of restoration of ammonium in soil (Table 5).

Table 5

Comparative analysis of sanitary-environmental indicators of soils

Indicators of the state of soils	"Vizhnitsky" NNP		
	recreation zone	stationary recreation zone	economic zone
Ammonium, mg/kg	1.8± 0.12	2.5±0.15	2.9±0.15
Nitrates, mg/kg	3.7± 0.25	5.0±0.32	5.4±0.20
Urease activity, μg/h (NO_3–NH_4) per g of soil	1.5±0.08	2.2±0.10	2.37±0.14

The results in Table 5 indicate the direct connection between enzyme activity and stability of the soil ecosystem. Thus, the transition to the recreational zone and economic zone leads to changes in stability of natural ecosystems due to more intensive livestock farming and development of agricultural land. Such changes lead in turn to a sharp increase in urease activity in human-transformed ecosystems. Similarly, an increase in recreational load affects the soil ecosystem. As it is known, the urease enzyme belongs to the class of hydrolases, which play a significant role in the hydrolytic splitting of organic substances and their transformation into plant-accessible nutrients. Consequently, the nitrate content increases and soil fertility progressively decreases in soils under excess anthropogenic loading.

Thus, the sanitary and hygienic indicators of soils in the zone of the recreation territory and in the economic zone do not create significant environmental danger. However, the problem of soil pollution with solid wood waste in the zone of economic activity remains urgent. The problem of collection and disposal of the waste is expedient for ensuring of the environmental safety of soils in the zone of the recreation territories.

7. A system of engineering solutions to reduce the level of environmental danger in the recreational territories of "Vizhnitsky" NNP

We identified threats and challenges for environmental safety of the zone of stationary and regulated recreation due to the monitoring of sanitary-microbiological and sanitary-environmental indicators of hydrosphere, atmosphere and soils in the territory of recreational zones of "Vizhnitsky" NNP. It was established that quality characteristics of the atmosphere of recreation territories are at the highest level and do not require improvement. Quality indicators of the hydrosphere meet current requirements but require stabilization guarantees. Therefore, it is advisable to improve the environmental state by intensification of biological natural processes of self-purification. It is advisable to develop measures for the disposal of wood waste, which is a source of microbiological pollution, for soils in the zone of the recreation territory and in the economic zone.

7. 1. Studying ways to intensify biological natural processes of self-purification

It is not expedient and even harmful to use reagent or other physical-and-chemical methods to purify surface water in the recreation zone. Only intensification of natural biological processes of purification is possible. The rational way to achieve intensification is to apply methods that would increase a mass transfer surface for biological environments, create conditions for their development and ensure functioning of a "biological conveyor", which provides high-quality biological natural purification from chemical and biological pollution. The use of special "Viya" fibrous carriers attached to the wooden structures of "pulp" creates such conditions. We studied them in detail earlier in study [40].

We considered the results obtained in the study [40] in terms of application of the "biological conveyor" method to ensure the environmental safety of surface waters of recreational territories. Additional studies were carried out on the composition of microperiphyton, which are inactivated on VYI carriers. The studies have found that two types of infusions (up to 500 individuals per 100 cm^2) occupy the dominant position among representatives of microperiphyton (organisms the size of 80–235 microns). 33 % of the total number of fouling biocenosis falls on rotifers (two species) and one species represent nematodes.

The following organisms were revealed in "VIYA" macroperiphyton (organisms the size of 2.5–100): 3 species of ephemeral larvae, stoneflies larvae, caddis flies larvae, chironomids and turbellaria larvae represented by one taxon respectively. Larvae of amphibiotic insects prevailed in the studied biocenosis of periphyton, mainly due to *Leuctra digitata* larvae of stoneflies (24 individuals per 100 cm^2).

The analysis shows that the method of the use of artificial media in surface waters of recreational areas proposed in the study [40] provides creation of a "biological conveyor". It intensifies natural biological processes of surface water purification.

7. 2. Determining optimal conditions for the disposal of wood waste by using it for production of biofuel

According to Fig. 4, the use of wood waste accumulated in the economic zone of a NNP for production of biofuels should ensure environmental safety in terms of soil pollution (and biological decomposition products – in terms of the atmosphere and hydrosphere). A prerequisite for using of wood wastes as biofuels is its preliminary pelleting or briquetting. Studies [28] established prospect of using sulfate soap for briquetting of wood waste as a binding agent. Sulfate soap is a waste of large-tonnage waste of the pulp-and-paper industry. Authors of paper [28] defined the basic stages of production of biofuels of wood waste: grinding, drying, mixing with a binding agent and briquette formation.

They also carried out additional studies to determine the critical humidity of wood waste in the process of their pre-drying before briquetting. One can represent the experimental results [28] by formula

$$\lg\left(w - w_p\right) = f\left(\tau\right), \quad (3)$$

where W is the current value of humidity, %; W_p is the equilibrium value of humidity, %; τ is the duration of drying, s.

As one can see in Fig. 6, it is possible to generalize the experimental points straight lines, and their intersection point will correspond to the critical humidity. Therefore, one can calculate the critical humidity of a material from equation:

$$W_{cr}=10^x+W_p, \quad (4)$$

where "x" is the ordinate of the intersection point of two straight lines, it corresponds to the critical humidity.

The equilibrium humidity was W_p=3 % for the experimental conditions.

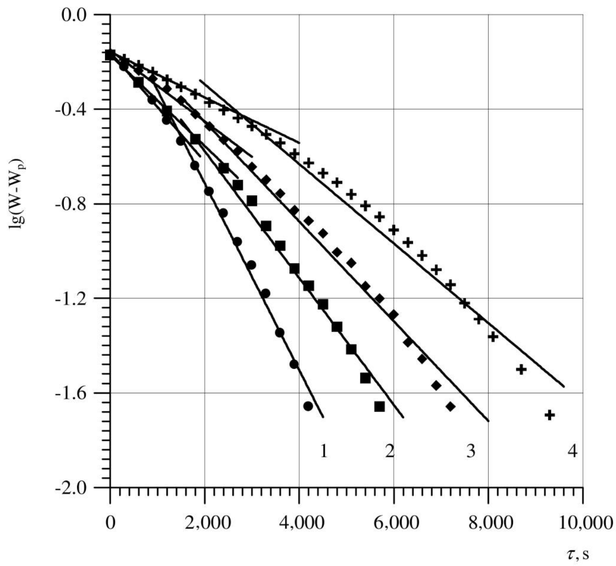

Fig. 6. Graphical method for determining critical humidity and time for its reaching the layers of different height T=100 °C, υ_0=4.2 m/s: 1 – $10\cdot10^{-3}$ m, 2 – $20\cdot10^{-3}$ m, 3 – $30\cdot10^{-3}$ m, 4 – $40\cdot10^{-3}$ m

8. Discussion of results of the effectiveness of engineering solutions for reduction of the level of environmental danger in the recreational territories of the NNP

We studied the intensification of biological natural processes of self-purification of surface waters with the use of VIYA artificial fibrous carriers for inactivation of microperiphyton and macroperiphyton. The obtained results indicated the positive dynamics of the growth of a number of microorganisms on the carriers. The advantage of the approach in minimization of hydrosphere pollution comparing to reagent or known biological methods is the absence of substances of uncharacteristic to ecosystems and organisms introduced into it. Purification occurs due to the intensification of biological processes of the ecosystem itself. One can apply the proposed approach successfully to ecosystems where exceeding of pollution levels did not reach the limit of loss of self-recovering capacity. The development of the study may be a search for alternatives of application of other types of media for inactivation of micro-ecosystems. One can determine the best option for specific cases in practice based on the analysis and comparison of the results. Thus, the analysis shows that the method proposed in study [40] for the use of artificial media in surface waters of recreational territories provides creation of a "biological conveyor". It intensifies natural biological processes of surface water purification.

It is proposed to use wood waste for creation of biofuels to utilize it. The first necessary operation is drying of wood waste to critical humidity levels. Using the experimental data (Fig. 6) and equation (4), we determined the critical humidity values of the investigated wood wastes, which were: for height $10\cdot10^{-3}$ m –W_{cr}=0.34 $\frac{\text{kg}\,H_2O}{\text{kg dry substance}}$; for height $20\cdot10^{-3}$ m – W_{cr}=0.36; for height $30\cdot10^{-3}$ m – W_{cr}==0.38; for height $40\cdot10^{-3}$ m – W_{cr}=0.4 The obtained results make it possible to determine the optimal drying time of wood waste for obtaining of the necessary results. The second necessary operation is briquetting, previously explored in detail. Studies [28] established the optimal binder agent concentrations fed to the briquette mass – (4–6) %, the optimal way of introduction of the binding agent into the press mass (homogenization of mixing), the optimum pressure of briquetting (500–990) MPa. Additional studies established the heat capacity value of the obtained biomass briquettes, which amounted to (25–29) MJ/kg. This makes it possible to state that one can obtain conventional biofuels as a result of the disposal of wood waste. There are no alternative solutions for the disposal of wood wastes found in the practice of known environmental measures. Thus, the implementation of the method proposed in study [28] for the utilization of wood waste from the economic zone of the NNP will make it possible to utilize it successfully and to ensure the environmental safety of recreation territories.

9. Conclusions

1. We have monitored the sanitary-microbiological and sanitary-environmental indicators of the hydrosphere, atmosphere and soils at the territory of recreational zones using an example of "Vizhnytsky" National Nature Park in the Pokut-Bukovynian Carpathians. Comparison of the results of water monitoring of economic and protected zones showed an increase in pollution by 2 times on average, which necessitates intensification of biological natural processes of surface water self-purification in the zone of recreation territories. The results of atmospheric air monitoring in the zone of the territories indicate its high quality indicators, which do not require any technical measures to improve it. It was established that sanitary-hygienic indicators of soils do not create significant environmental danger in the zone of the recreation territory and in the economic zone. However, the problem of soil pollution by solid wood waste in the zone of economic activity remains urgent. The problem of collection and disposal of the waste is urgent to ensure the environmental safety of soils in the zone of recreation territories.

2. We developed a system of engineering solutions for reduction of the level of environmental danger in recreational territories on the example of "Vizhnytsky" National Nature Park of the Pokut-Bukovynian Carpathians. It is proposed to use the previously studied fibrous carriers to intensify biological natural processes of self-purification. The additional studies confirmed inactivation of microperiphyton and macroperiphyton "biological conveyor" carriers. It is proposed to use wood waste for production of biofuels to ensure environmental safety in terms of pollution of soils of NNPs with wood waste. We proposed sulfate soap, which was studied previously as lignin containing waste, as a binder agent. Additional studies found that the heat capacity value of the obtained biomass briquettes was (25–29) MJ/kg. Therefore, it is possible to argue about obtaining conventional biofuel as a result of the disposal of wood waste.

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