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Sustainable Development

SDEV'2022

SUSTAINABLE DEVELOPMENT — STATE AND PROSPECTS

COLLECTIVE MONOGRAPH

Editors
Mirosław Borkowski
Oleksandr Moroz
Mykhailo Paslavskyi

WYDANIE ONLINE PDF

GSW WYDAWNICTWO

The 3rd International Scientific Symposium

SUSTAINABLE DEVELOPMENT — THE STATE AND PROSPECTS

26-29 January 2022, Slavske (Lviv region, Ukraine)

Lviv Polytechnic National University
V. Chornovil Institute of Sustainable Development
Gdańsk School of Higher Education

PREVIOUS RELEASES

Sustainable development — state and prospects,
Mirosław Borkowski, Oleksandr Moroz, Mykhailo Paslavskyi (eds.),
Gdańsk 2020, Wydawnictwo GSW, ISBN 978-83-66270-12-1
https://gsw.gda.pl/wydawnictwo/sustainable-development_112

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seria NAUKA i SPOŁECZEŃSTWO

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First edition, Gdańsk 2023

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www.gsw.gda.pl/wydawnictwo

ISBN 978-83-66270-30-5 Nr kat. [130]
www.gsw.gda.pl/wydawnictwo/SDEV-2022 → →

Seria: Nauka i Społeczeństwo, Nr 5
Seria wydawana jest wspólnie z Kancelarią Doradztwa Gospodarczego i Prawnego „Filar” z siedzibą w Gdyni

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About food waste in the hospitality industry

Abstract
In the context of the COVID-19 pandemic, the number of people affected by hunger has increased worldwide. About 50 million people die prematurely due to malnutrition. This situation can at any moment be reborn in a serious misfortune of life. In a difficult situation, they found themselves in poor middle-class wars, and even highly developed groups of countries. This situation can at any moment be reborn in a serious misfortune of life. In a difficult situation, they found themselves in poor middle-class wars, and even highly developed groups of countries. 2.3 billion people in the world do not have the opportunity to buy aging livelihoods. The same number of products are used. Worldwide, approximately 14% of livestock production is lost in the chain among buyers and sold to retailers. A significant number of products are also consumed in detail and consumption. It costs 17% (1.3 billion tons) of the world's largest livestock production (11% in households, 5% in gastronomy and 2% in the retail trade). UN analysts note that if the problem of wasting life has always affected developed countries, it has now become a problem all over the world. It is estimated that such waste costs the world economy more than 1 trillion dollars a year. The state of life loss is 38 percent of total energy consumption in the world system of life. This is one of the most important problems of our time, the scale and consequences of which are still hidden from consumers. It should be noted that a significant number of funds are intended for the production of livestock. The waste of life leads to excessive consumption of fresh water and fuels for bathing, which, together with methane emissions from the decomposition of life, leads to global climate change. The United Nations calls on the region to engage in waste management and reduce it by half by 2030. There are a number of global initiatives that should prevent the negative impact of the irresponsible attitude to life and prevent the graves of hunger. I belong to them in general, the creation of a network of banks of life. Thanks to the educational activities of the UN, FAO, life banks and various organizations of traders and volunteers and joint movements, which promote appropriate consumption and prevent it, we avoid it in vain. Limiting the consumption of livestock per person in the area of detailed trade and gastronomy is important for the establishment of the bards of outstanding chains of products and deliveries. Get to the safety of life and go to the bard for a special hostess. The HoReCa sector is also one of the most powerful producers of consumer waste, which is why it is important to limit strata and waste of food. Among the considerations for solving the problem of limiting the expenditure of livelihoods in the hotel industry, it is important to note in general terms: the urgent use of food stocks and raw materials; optimal cooking; division of livestock (distribution of livestock according to the date of importance among those in need); cooperation with livestock banks, which distribute significant livelihoods among charitable organizations; connection with mobile apps selling meals from cafes and restaurants with a discount of 50-80% (among such programs the best known are "Too Good To Go", "Karma", "Olio", "Approved Food", "Clearance XL", etc.); work with consumers at the expense of appropriate consumption of food. Much attention should be paid to contemporary wasteful consumption at the legislative level to give impetus to the introduction of food waste prevention mechanisms not only at the agricultural, food production and nutrition level, but also at the consumer level, as reducing food losses is impossible without sustainable food chains. The current strategy of limiting the waste of livelihood must include supply, demand, operations and markets. We must rely on the creation of a supply chain, which is balanced not imaginatively, but conveniently with the project at all stages – from production to distribution and consumption. It requires cooperation within the entire ecosystem of life.

Introduction

Against the background of the COVID-19 pandemic, the number of people affected by hunger has increased – in 2020 the number of people starving in the world increased to 811 million, and every third person did not have access to sufficient food. At the same time, many products are thrown away. Worldwide, about 14% of food production is lost between harvesting and retail. 17% (1,3 billion tons) of total world food production is spent in vain (11% in households, 5% in catering and 2% in retail) [5]. Such processes have given rise to the concept of smart consumption, which has become a recent trend.

Analysis of the literature

The scientific vision of waste management taking into account environmental results was initiated by V. Vernadsky, V. Dokuchaev, and continued in the studies of V. Gorobets, V. Novoseltseva, A. Pig, J. Hartwick and others. The reasons for waste generation and their role in the state's environmental policy have been the subject of scientific research by A. Bykov, G. Vyhovska, A. Kuzin, V. Petrov, and others. The works of S. Baranovsky, O. Kryvchun, G. Martenyuk, I. Sedikova, I. Sokolovskaya, V. Tymchak, O. Sheremet consider theoretical and methodological approaches and practical recommendations for integrated waste management, improving the environmental and economic efficiency of recycling. Trends in the development of hospitality industry enterprises are reflected in the scientific works of O. Davydov, J. Volkovska, N. Onyschuk, N. Kondratenko, L. Obolentseva and others. However, the theory, methods and methodological basis of integrated FW management in the hospitality industry are underdeveloped and require further research.

Topicality

The aim of the research is considered to be the peculiarities of the formation and possibilities of reducing food waste (hereinafter – FW) in the hotel and restaurant industry. In accordance with the goal, it is necessary to solve the following tasks: to determine the nature and nature of FW in the hospitality industry; assess the scale of their formation, accumulation and loss; consider public and governmental initiatives to reduce food waste in different countries; develop recommendations for reducing food losses and reducing the share of FW in hotel and restaurant facilities.

Research results

Food losses and food waste mean a reduction in the amount of food intended for human consumption at all stages of the food chain from harvest to mass consumption, regardless of the reasons that cause them [5]. FW means food intended for human consumption, which is discarded or spoiled at the stage of consumption – regardless of the reasons [6]. These include edible as well as inedible parts of food that are removed from the food supply chain and that can be recovered or disposed of. In addition, FW can be grouped into three types: first, waste that can be avoided is food that was once edible but became inedible before disposal; second, unavoidable wastes that are non-edible components of the product, such as eggshell; third, food waste that cannot be avoided, this applies to certain wastes that are generated from time to time, such as potato peelings.

The Food and Agriculture Organization of the United Nations estimates that about 30% of the world's food production, including fruits, vegetables, oilseeds, meat, dairy products and fish, is lost or wasted [3]. About half of these foods are edible. That's 1.3 billion tons a year – enough food to feed 2 billion people. Such waste is estimated to cost the world economy more than 1 trillion dollars a year. The structure of food costs is as follows.

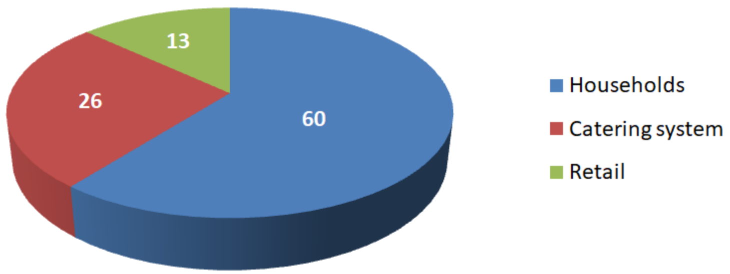

Fig. 1. The structure of food costs

The study of the geographical organization of the amount of food waste is as follows (Fig. 2). In developing countries, this percentage of waste can be caused by problems in the production process or lack of storage. In more affluent countries, the problem lies at the very end of supply – in consumers. They throw away more than 30% of the food they buy [8].

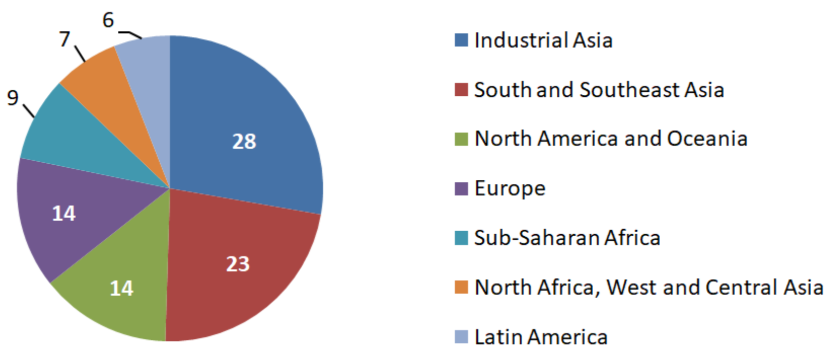

Fig. 2. Distribution of food waste (100% = 1.5 quadrillion calories)

If we analyze the local situation in different countries around the world, we see that the largest producers of food waste are the world's largest countries – China and India.

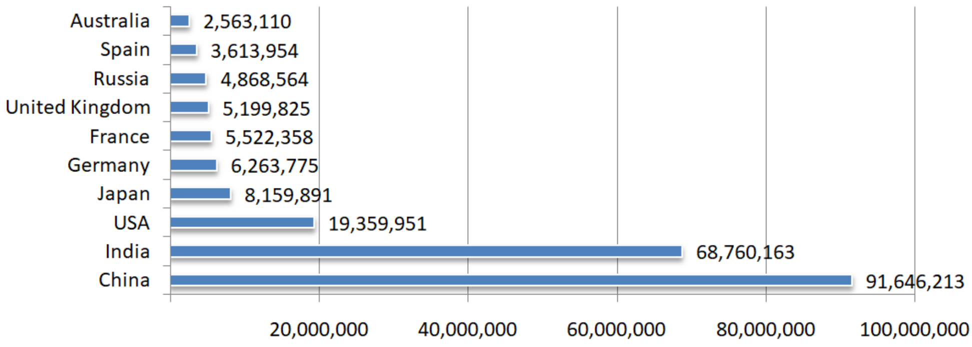

Fig. 3. Organic cost scale (tons per year) [2]

Hospitality companies are powerful producers of FW. Food waste in the hospitality industry has become a major problem, given that its contribution to total food waste in 2019 was about 12%.

Let's outline the directions for solving the problem of reducing FW in the hospitality industry.

Food sharing is the distribution of food with the appropriate expiration date among those who are interested in them [8]. Today, food-sharing projects save about 7,000 tons of food a year. In the medium term, the potential annual volume of food saved could reach 1 million tons − and this is an opportunity to provide food for about 1.3 million people, as well as to run a food business with an expiration date.

The modern method of reducing food waste is *food banks* or food bank. These are non-profit charitable organizations that organize the transfer of food products (including expired goods) from various restaurants, shops or individuals to people in need. Food banks exist thanks to volunteers who help in finding suppliers of products, sorting, quality control, transportation of products. Food banks solve two problems at the same time: environmental and social. Every year, they distribute thousands of tons of food among the millions of people who need it.

There are three largest food banking networks in the world: the Global Food Banking Network (GFN), Feeding America in the United States and the European Federation of Food Banking, which unites 24 European countries.

The Global Food Banking Network (GFN) has 943 members from more than 80 countries, including Europe, South America, South Africa and Asia, the Middle East, Canada and Australia, which together help more than 10 million people [4, 5]. Two years ago, in the wake of the COVID-19 pandemic, the organization launched a new strategic plan that renewed its mission to feed the world's hungry by uniting and developing food banks – and pledged to support local food banks to serve 50 million people suffering from hunger until 2030.

The largest national organization in the United States is Feeding America, which has been helping the starving for more than 40 years. The organization is supported by individuals, charities, businesses, enterprises and the government [7]. Feeding

America not only feeds people on the ground, but also raises awareness about the problem across the country, promotes cutting-edge research among the public, and encourages investment in marketing and communications. Feeding America participates in programs that protect people from hunger with the help of staff working in Washington DC, as well as through the Center for the Fight against Hunger and the Massive Center for Online Human Rights. The Hunger Center consists of an online community of more than 150,000 people who help support hunger programs at the federal, state, and local levels. Feeding America invests in research initiatives such as the Annual Meal Map Report and the Four-Year Hunger in America Study (HIA) [4].

The European Food Banks (FEBA) is a European initiative that brings together 240 food banks in 24 EU countries. FEBA distributes tons of food products among 5 million people annually. The main goal of Food Banks is to prevent food waste and promote food security. "Supply" is ensured in compliance with hygiene requirements through the return of food surpluses and/or donations from sectors such as agriculture, processing, food production and distribution, hospitality (HoReCa). Although reconstituted foods may no longer be sold, they must be safe for consumption at all stages of the supply chain. In addition to collecting surplus food, food banks also encourage the public to create special containers in supermarkets, schools, etc. They participate in international, EU and/or national food aid programs.

Some system initiatives operate in different countries in Europe and Asia. In France, for example, shops are required to donate unsold food that can still be eaten free of charge to charities or to feed it to animals. Violators face a fine of 75,000 euro. In addition, French legal practice since 2015 provides for the mandatory introduction of educational programs to combat food waste in educational institutions in the country.

In 2021, Italy also introduced laws to reduce food waste. It repealed a provision that provided for a penalty for the free distribution of food with an expiration date. There are even benefits for farmers and supermarkets that donate food to charity. In addition, the Italian government has allocated 1 million euro for an initiative to offer "food baskets" (leftovers) to families who order food delivery.

More than 18 billion kg of food waste is dumped in China every year. This amount of food is enough to feed 30-50 million people. About 25% of the waste was basic food and about 18% − was meat [3]. In August 2020, the local government campaign "Operation Empty Plates" began reducing waste, including encouraging food outlets to limit main course orders to one less than the number of customers [3]. As of December 2020, China has passed the Food Waste and Food Waste Act, which provides for penalties if food outlet owners mislead customers, accompanied by over-consumption and increased food waste.

In 2011, the Ukrainian food bank KMBF Foodbank started operating in Ukraine. In 2021 "Tarilka" food bank opened in Lviv. The organization operates in 22 regions of Ukraine. The organization's partners have different directions of activity. Many of them are related to the restaurant industry, such as! FEST Holding and Kumpel Group, the Cult of Bread.

Volunteer programs provide tools that restaurants can use to achieve this goal, track their own expenses, and report to guests.

Zero Foodprint (ZFP) helps restaurants get zero waste. They begin their life cycle assessment work with restaurant partners, providing guidance on areas where changes are needed, from packaging to storage and waste. To further reduce their footprint, participating restaurants also add a small fee to their bills, one percent, which helps fund grants for restorative agriculture projects [1, 3, 8].

Grace's Foodprint Group is working to enforce work standards in restaurants and hospitality, helping to reduce waste at every turn. The Foodprint Group, which has worked with approximately 100 sites since its launch in 2017, including customers such as Google, Eataly and Dig, uses a daily waste tracking tool as well as signage and other tools to help restaurant and hotel partners implement procedures without waste, reducing their waste in all streams. Only 10% or less goes to landfill; the rest – food, packaging and everything else – is reused, processed, composted or donated [1].

Organizations such as Rescuing Leftover Cuisine and Rethink deliver surplus food from restaurants, hotels and catering establishments to nearby homeless shelters, while Rethink helps restaurants and catering partners convert surplus food to food banks and other needy organizations [19]. The Blue Hill Restaurant in New York City aims to reduce food waste by using food that could spoil food or using it as food on the Blue Hill Farm.

Mobile applications and games. The new Copia application is designed to reduce losses. Entrepreneurs can use this application to plan the selection of surplus food, as well as to provide food to charities on demand. Interestingly, the implementation of the initiative from the social project "Ukraine without garbage" and Pernod Ricard Ukraine, web game Trash Hunter. This game is designed for both children and adults. With its help, the authors want to spread knowledge about sorting and responsible consumption. At the beginning of the game, there is a block with information about eccentric garbage monsters and how to deal with them. The next block is the game itself, in which you can test your knowledge. Six missions have been developed: plastic, paper, metal-glass, compost, dangerous missions and a big game. As a result, the player acquires knowledge about the rules of sorting, an information base and a good mood. This is a great educational initiative, the main idea of which is to prevent garbage from flooding the real world. It draws more attention of Ukrainians to environmental issues. The game can be found on the site of the same name trashhunter.com.ua.

Among other things, it is worth mentioning other specific steps to reduce FW:

1. Measurement of food waste. By simply tracking food consumption and waste, many restaurants find the opportunity to reduce production by meeting customer demand.
2. Excess food plan. Restaurant kitchens often end up with surplus food. If you do not use some ingredients, they may end up in the trash. Therefore, you need to take care of future actions in advance.

3. Composting. Some food companies use kitchen compost to enrich the soil in orchards and orchards or as a natural fertilizer for landscaping. Composting also reduces the impact on the environment.
4. Donation. There are many charities that take food from restaurants and other food businesses and distribute it to people in need.

Conclusions

1. Thus, an important stage in the development of our society was the realization of the importance of reasonable consumption of resources of our state and the proper organization of assistance to people.
2. Entrepreneurs are increasingly adjusting their work to the previously mentioned ideas. They finalize the menu, coordinate partnerships with charities and food banks, and are interested in the benefits of composting in today's market.
3. It is important now to reduce the cost of food to the lowest possible level, first at the national level and then at the international level. An effective food waste reduction strategy must be based on a supply chain that is sustainable not by default but by design at all stages, from production to distribution and then to consumption throughout the food ecosystem.

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Wydawnictwo GSW • Gdańsk 2023 • ISBN 978-83-66270-30-5

UDC 502.65:620.92:551.508.54

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Construction of wind-energy facilities as a direction of the disturbed by mining activity territories use

Abstract
The development of human society and the satisfaction of its needs takes place with the constant extraction and further use of natural resources. The result is a significant generation and accumulation of industrial waste. Waste management is one of the most painful problems today and is a priority in all developed countries. In Ukraine, because of the generation of large amounts of waste, this problem has become particularly acute. A prerequisite for the transition of society to sustainable development, defined by the "An Agenda for the 21st Century", is the introduction of the principles of sustainable nature management in the economic activities of countries. Mining activities are one of the main sources of environmental contamination through metals released due to soil erosion. High concentrations of metals in soils and consequently into soil groundwater could have negative effects on terrestrial ecosystems and could pose potential health risks. This study is based on the principles of a systematic approach to the prospects of using of the territory of State Enterprise (SE) "Rozdil Mining and Chemical Enterprise (MCE) »Sirka«" for the construction of renewable energy facilities. Today, such lands include the territories in the zone of influence of SE "Rozdil MCE »Sirka«", which was founded in 1953 in connection with the development of a fairly large Rozdil sulfur field. It is concluded that current mining practices need to change and contribute to community development with more equity, and to protect better natural resources and ecosystems to be environmentally acceptable and compliant with sustainable development objectives. As the problem of non-implementation of projects of reclamation and remediation of the territories disturbed by mining and chemical activity still remains acute in Ukraine, it is no less important to ensure sustainable development of the territories of influence of mining and chemical enterprises.

Introduction

In line with the aims of the Paris Climate Agreement, a signed and ratified document under the United Nations Framework Convention on Climate Change (UNFCCC) to regulate measures to reduce carbon dioxide emissions, there is a steady trend in the world to develop renewable energy sources (RES) and gradually replace traditional generation. In recent years, Ukraine has seen a gradual increase in installed RES capacity, primarily solar and wind power plants of various installed capacity, primarily due to the main economic stimulus tool – the system of "green tariffs", which are approved pegged to the Euro and guaranteed until 2030 [1].

Analysis of the literature

Studying the current state of achievement of sustainable development goals and effective ways of transition to sustainable development is important for both research and practical needs, as it allows to live in a stable ecosystem. The study of the ecological component of development needs special attention in this issue, because a prerequisite for the transition of society to sustainable development, defined by the "An Agenda for the 21st Century", is the introduction of the principles of sustainable nature management in the economic activity of countries.

Environmental pollution is one of the most serious global challenges. Every year the issue of environmental pollution becomes more acute. Deterioration of the ecological situation is helped by the constant release of pollutants into the environment, which cause an increase in the greenhouse effect, acid rain, ozone holes, pollution of the oceans and reduced soil fertility.

As a result of industrial production in areas of location of various enterprises and places of extraction of minerals, and also quite often near settlements there are the centers of industrial desert with insignificant vegetation and even without it. In the ecological aspect, mining facilities form a conditional exclusion zone with indicators of forced man-made impact on the components of the environment. The formed anthropogenic landscape is characterized by significant negative quantitative and qualitative changes in influence of the mining complex. The soil here is contaminated with industrial emissions, construction waste, ash from thermal power plants, rock extracted from mines and quarries because of underground work, flooded with petroleum products, household waste, etc. In such areas, the soil is so spoiled that it loses fertility. In 2000, the mass of production waste in the world exceeded 100 billion tons; up to 30% of them are solid waste from industry, urban and agriculture.

The industrial load on the environment from emissions of enterprises per 1 km^2 of the country's area is about 6.5 tons, per capita – more than 80 kg per year. Ukraine has not yet gained serious experience in the field of industrial and household waste disposal: only 5-10% of waste is recycled, and the rest is accumulated in the form of landfills, which become objects of environmental danger. Violation of ecological balance from the impact of the mining and chemical enterprise leads to geochemical and geophysical anomalies of anthropogenic origin. In the area of influence of the mining and chemical enterprise and production wastes, there are zones of the increased concentration of separate chemical elements and their connections [1-7].

The first idea of creating tailings was the safe storage of industrial waste. But in Ukraine, tailings are often turned into objects of chronic pollution.

Within the Dniester River basin, 32 tailings ponds with 162 million tons of waste have been found. The most dangerous objects in the Dniester basin are the tailings of three enterprises that are in critical condition and need urgent measures to prevent accidents: SE "Rozdil Mining and Chemical Enterprise »Sirka«" (SE "Rozdil MCE »Sirka«") (three tailings ponds, approximately 108.9 million tons, distance to the Dniester River is 380 m) LLC "Oriana-Eco" (three tailings, 26 million m^3)

PJSC “Stebnyk Mining and Chemical Enterprise »Polimineral«” (one tailing, 12.74 million m³).

At SE “Rozdil MCE »Sirka«” sulfur production waste generated as a result of former open-pit sulfur production is stored in tailings ponds located in different parts of the field, and waste from the production of mineral fertilizers – in a phosphogypsum dump.

Also, on the industrial site of the enterprise, the modifier of the MG type made of tar residues is stored. 10 years ago, a canal was created from the man-made lake Hlyboke to the cross-border river Dniester without treatment facilities [8, 9].

Favorable economic conditions for the development of RES contribute to the search by investors for areas suitable for the design and construction of solar and wind power plants. Among the requirements for such areas are the purpose of land, among which preference is given to areas outside settlements, non-agricultural land with energy infrastructure – power lines, transformer substations, the availability of electricity consumers, energy facilities that could maintain energy balance in case of unstable RES operation, etc.

Nowadays, such lands include the territories in the zone of influence of SE “Rozdil MCE »Sirka«”, which was founded in 1953 in connection with the development of a fairly large Rozdil field.

To date, two solar power plants have been built in the area of influence of “Rozdil MCE »Sirka«” – on hydraulic dumps No. 1 and 2 (Fig. 1 and 2).

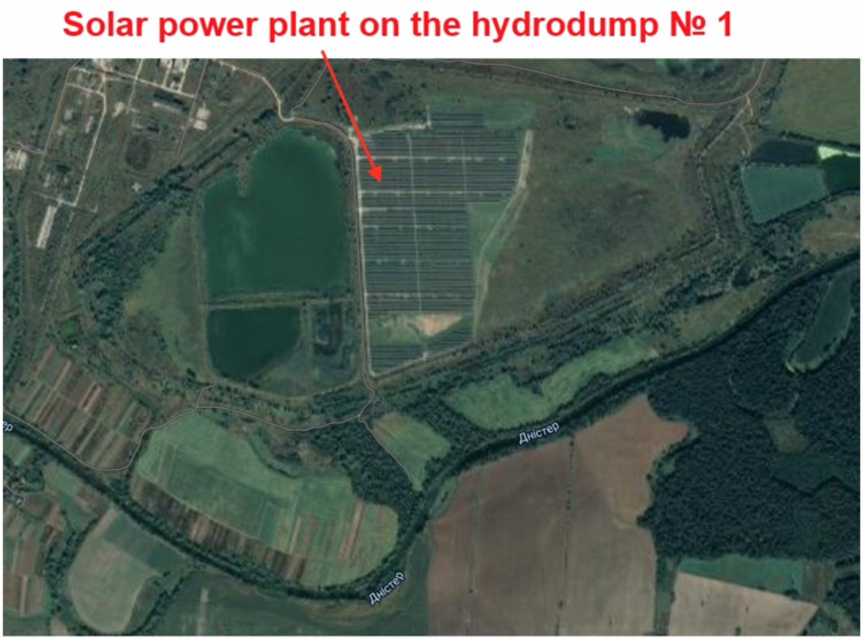

Fig. 1. Solar power plant on the hydro dump No. 1

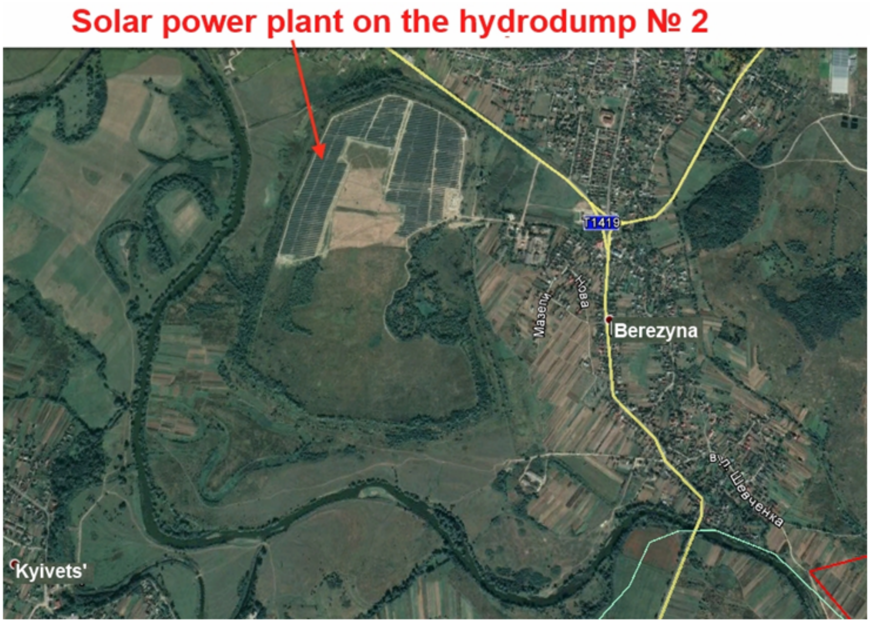

Fig. 2. Solar power plant on the hydro dump No. 2

This enterprise developed rapidly in the 1950s and 1980s, when sulfur ore deposits were discovered, geological exploration was carried out, three quarries (Pivdennyi (South), Tsentralnyi (Central) and Pivnichnyi (North)) were put into operation alternately, a concentrator and a complex plant were built. mineral fertilizers, industrial waste storage facilities, and the production of mineral fertilizers amounted to about 800 thousand tons per year.

The facilities of the Rozdil enterprise occupy the floodplain and the floodplain terrace of the Dniester River valley within the small rivers Barvinok and Kolodnytsia. Man-caused objects and formations occupied an area of 2200 ha, including: residual quarry excavation – 263 ha, external dumps – 853 ha, tailings pond No. – 220 ha, tailings pond No. 2 – 140 ha, settling pond – 130 ha, accumulating basin – 127 ha, sulfur production – 125 ha, hydraulic loam dump – 125 ha, complex mineral fertilizer plant – 93 ha, phosphogypsum dump – 58 ha, biostands – 18 ha.

Sulfur deposits near Novyi Rozdil were discovered in the middle of the 20th century, where the development of a sulfur deposit was started. Over time, in addition to the quarry, began to work enterprises specializing in the production of ground sulfur, plant protection products – fungicides and complex fertilizers. The production of sulfur-based mineral fertilizers amounted to about 800 thousand tons per year, which involved about 12 thousand workers.

In the early 1990s, sulfur production stopped, the process of restructuring the mining and chemical plant began on an area of about 22 thousand hectares and has a developed infrastructure, energy supply and water supply system, railway.

As of 2000, the Rozdil sulfur deposit has been fully developed – all explored deposits removed from the subsoil, disturbed by mining landscapes within the study area are reclaimed and brought to a safe for humans and the environment in accordance with the developed complex project.

The territory of SE "Rozdil MCE »Sirka«" is located in the floodplain and floodplain terraces of the Dniester River valley, limited by small rivers Barvinok and Kolodnytsia and covers an area of about 22 km^2 (Fig. 3) [10].

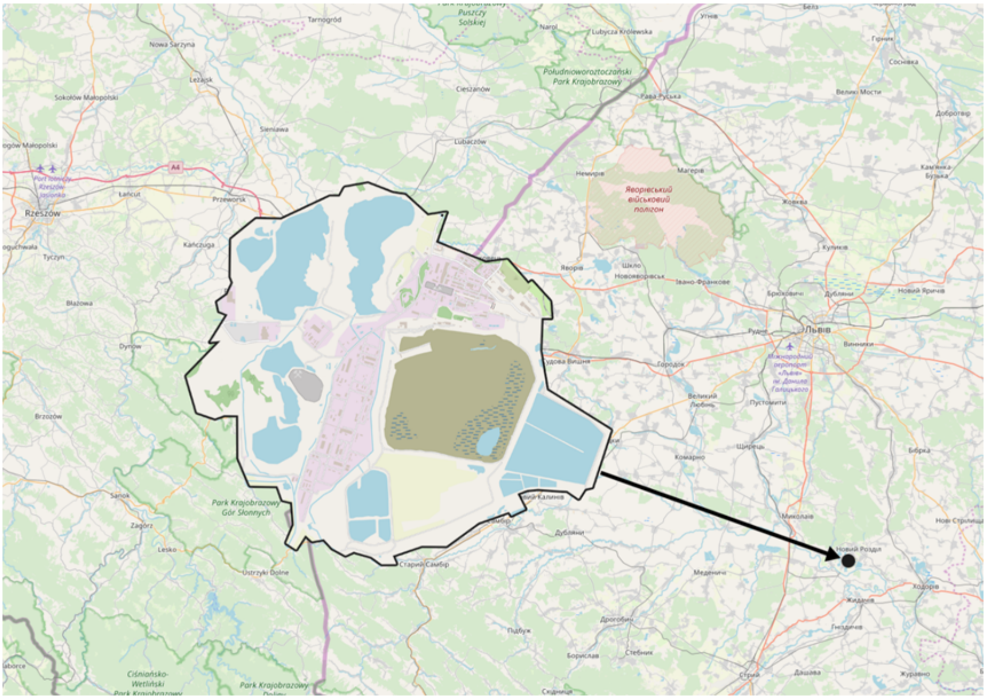

Fig. 3. Location of the study area

Source: OpenStreetMap.

Wind energy is a branch of alternative energy that specializes in the conversion of wind kinetic energy into electricity.

The source of wind energy is the sun, as it is responsible for the formation of wind. The Earth's atmosphere absorbs solar radiation unevenly due to the inhomogeneities of its surface and different angles of incidence of light at different latitudes at different times of the year. The air expands and rises, forming streams. Where the air is heated more, these flows rise higher and are concentrated in low-pressure zones, and colder air rises lower, creating high-pressure zones. The difference in atmospheric pressure causes air to move from the high pressure zone to the low pressure zone at a proportional speed. This movement of air is what we call wind.

Advantages of wind energy:

- low cost – wind energy can compete with nuclear, coal and gas energy;

- zero cost of the fuel part, the energy source is inexhaustible and is present in unlimited quantities;
- environmentally friendly energy – energy production is not accompanied by carbon dioxide emissions;
- wind energy has no risks associated with volatile fossil fuel prices;
- reliability of supplies – wind energy avoids dependence on energy imports;
- modular design, quick installation;
- power supply is comparable in volume to traditional generation methods;
- wind energy does not interfere with agriculture and industrial activities near wind farms.

Topicality

Any investment project that receives income from the production and sale of certain products begins with forecasting the productivity of production. The product that a power plant produces, and sells is electricity.

To assess the performance of a traditional type of power plant (HPP or NPP) it is sufficient to perform direct calculations, the initial data for which are the parameters of power equipment and energy pecypci. For wind power plants (WPPs) the energy resource is wind, the energy potential of which cannot be estimated by direct calculations due to the changing nature. However, in each area the wind of the masses is a long-term trend, the study of which is of paramount importance for justifying the economic efficiency of investment in wind farms [11].

To assess the performance of the wind farm, wind speed observations are required directly at the selected site of the wind farm at the height of the rotor axis of the selected wind turbine. Since the useful life of wind turbines is 20-30 years, the sample data should have sufficiently long observation periods. The World Meteorological Organization (BMO) recommends using at least 10-year wind speed time series samples to account for long-term trends [12].

But performing wind speed measurements during such a period is wrong. Therefore, the method of mathematical modeling of the horizontal wind profile (the so-called MCP method – "measurement-correlation-prediction") was developed [13], which allows you to easily replace long-term wind speed observations at the wind farm site with relevant stock data measured (possibly for others goals) on a nearby site.

The longest series of information on wind speed are represented by series of observations of meteorological stations (MS). There are about 200 such MSs in Ukraine. This means that the average density of coverage of the country by these sources of information is about one MS per square with a side of 55 km. For most of Ukraine, such a density is sufficient for spatial interpolation of wind speed by the MCP method.

But in recent years (especially after 1990), the reliability of MS data on wind speed has deteriorated significantly. The fact is that the land near the meteorological stations came out of state ownership, and their owners began to dispose of them without taking into account the requirements of the MS on the measurement of wind characteristics. Obstacles (trees, houses, etc.) to the flow of air were created, anemometers and weathervanes began to record distorted data, and anemometers and weathervanes began to record distorted data.

As a result, a significant number of MS were removed from the list of valid sources of long-term data on wind characteristics.

As meteorological stations have become rather uneven, and distances between MSs now sometimes exceed 100 km, there is a need to find other approaches to obtaining long-term data on the wind regime of the territory [14-17].

Devices for measuring wind speed – anemometers [18, 19] – differ primarily in the design of the sensor. Cup (winged, ultrasonic and thermal anemometers), winged, ultrasonic and thermal anemometers are most often used. The first two types have a rather complex mechanical design, so they are not suitable for Ad-hoc measurements. The third type is very difficult to debug. Therefore, thermal anemometers are best suited for Ad-hoc measurements.

The purpose of the work is to research a systematic approach to the prospects of using the territory of SE "Rozdil Mining MCE »Sirka«" for the construction of renewable energy facilities.

Research results

The principle of operation of the thermal anemometer is that the temperature sensor heated to a certain temperature is cooled by wind. The temperature of the sensor decreases depending on the intensity of its heat transfer, i.e. the speed of air flow that blows the sensor. Therefore, the result of temperature measurement is a function of wind speed. But the degree of cooling of the wind speed sensor also depends on the temperature of the air that blows it, ie the wind itself. Thus, the thermal anemometer has a significant methodological error associated with its operating conditions.

The heating temperature of the sensor of the thermal anemometer should not pose a danger to humans, so it should not exceed 60ºC. And the operating temperature of the anemometer is from -20ºC to +40ºC. It is possible to reduce the error associated with air temperature due to the fact that with relatively small changes in temperature, the heat transfer conditions change little. However, changes in the operating temperature of the anemometer from -20°C to +40°C cannot be considered small. Therefore, it is advisable to reduce the heating temperature of the sensor. However, then the error in measuring the temperature change of the sensor under the influence of wind increases. And there are specialized high-precision temperature meters, they should not be used for Ad-hoc measurements.

This contradiction can be reduced by using high-sensitivity temperature sensors – thermistors [20]. Their temperature coefficient of resistance reaches 4%/ºC. But they have significant deviations of the conversion function (CF) from the nominal – up to 20% at +20ºC and up to ±5% by temperature coefficient. Therefore, it is necessary to pass to individual AF of the thermistor.

Discussion of results

Method of transition to individual thermistor conversion function

Traditionally, the transition to an individual conversion function is based on reference equipment. But Ad-hoc measurements should be based on natural phenomena and widely used equipment. The advantages of thermistors, in addition to high sensitivity and low cost, are that the resistance of widely used thermistors at 20ºC is in the range from 10 to 1 Ohms and strict compliance of their CF exponent [20]:

$$R_T = A \cdot e^{B/T}, \tag{1}$$

where R_T – thermistor resistance at temperature T (in Kelvin); A, B – its parameters.

Therefore, to switch to an individual CF, it is enough to know the resistance of the thermistor at two temperatures. For Ad-hoc measurements it is advisable to choose these temperatures 0ºC (ice melting temperature, it can be created by freezing boiled water in the freezer) and 36.6ºC (body temperature of a healthy person, it can be checked with a medical thermometer). The errors of these temperatures do not exceed ±0.2ºC. It is impractical to measure thermistor resistances with a digital tester, its error is too large. It is better to measure close to the measuring range voltage drops on series-connected thermistors and a resistor. Then the error of relative measurements of resistance of two thermistors at both temperatures will not exceed double error of discreteness (for the cheap digital tester – 0,1%). According to the results of measurements we find the parameters A, B of both thermistors according to the formulas:

$$B = \frac{\ln R_{T1} - \ln R_{T2}}{1/T2 - 1/T1}, \quad A = \frac{R_{T1}}{e^{-B/T1}}, \tag{2}$$

where R_{T1}, R_{T2} – the resistance of the thermistor, respectively, at temperatures $T1$, $T2$ (in Kelvin).

Setting the temperature measurement channels

It is advisable to use common data acquisition units, such as USB6009, to measure the resistance of thermistors in the thermoanemometer scheme [21]. But the scheme of the input circuit of such units is complicated by the need to measure the voltage in the range of ±10V when powered by a USB port voltage of +5V. Therefore, to adjust the channels for measuring the temperature and wind speed of the thermoanemometer, it is advisable to use the following method:

1. Determine the parameters A, B of thermistors for measuring temperature and wind speed.
2. Calculate the resistance of thermistors of temperature and wind speed in temperatures from -20ºC to +40ºC with a step of 5ºC.
3. Assemble the scheme of Fig. 4 (transistor V1 locked). At the MO2 resistance store, set the resistance of the thermistor at -20°C of the corresponding channel and use MO1 to set the display USB6009, which corresponds to 1V. Replace the MO1 resistance store with a constant resistor of slightly higher resistance.

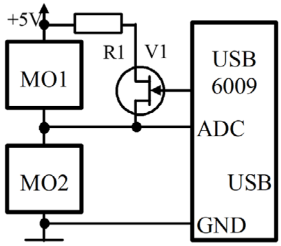

Fig. 4. Scheme for measuring the resistance of thermistors

4. Setting the resistance of the store MO2 equal resistances of both thermistors at all temperatures calculated in paragraph 2, record the results of the conversion unit USB6009.
5. According to the results of paragraph 4 to approximate the resistance resistance in the temperature of the channels for measuring temperature and wind speed.
6. In the wind speed measurement channel replace MO2 with the appropriate thermistor, measure the current air temperature with it, open transistor V1, warm up the thermistor for 5 minutes. Close V1 and immediately measure the temperature of the heated thermistor. Determine the thermistor overheating by the temperature difference before and after heating. The selection of R1 should set the value of overheating when the error of measurement of wind speed is minimal.

Thermoanemometer calibration technique

The described operations of identification of individual CF thermistors and setting of temperature measurement channels provide sufficiently accurate measurement of air temperature and thermistor overheating. However, these operations do not provide sufficient accuracy in measuring wind speed – it is determined by the decrease in temperature of the superheated thermistor under the action of wind. That is, the result of measuring the wind speed depends on the heat transfer conditions of the superheated thermistor with the surrounding air (its heat transfer coefficient). Therefore, to ensure accurate measurement, it is necessary to determine the through CF of the measuring channel. The problem is complicated by the fact that this through CF has both wind speed and air temperature. Thus, the through CF is a nonlinear surface, and a large amount of experimental research is required to identify it. It can be reduced by recognizing the wind speed by a pre-trained neural network by air temperature and reducing the temperature of the superheated thermistor, similar to [22].

To train the neural network, it is necessary to create a training sample based on the results of experimental determination of the decrease in overheating temperature according to the specified with sufficient accuracy wind speed and ambient temperature. For this purpose, it is necessary to make the stand which sketch is given in Fig. 5. It contains an electric motor EM, on the axis of which is mounted a rocker arm RA with an overheated thermistor T at the end and a counterweight C at the other end. The number of revolutions of the EM per second is set by the voltage regulator

VR and is measured by the MS system, for example, by the number of interruptions of light flux by the rocker arm RA.

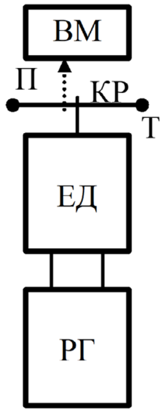

Fig. 5. Measuring channel calibration stand

The velocity of the thermistor T relative to the calm ambient air, ie the speed of "wind", which occurs during rotation, is calculated as:

$$S = L/\tau = 2\pi Rn/\tau, \qquad (3)$$

where L – the distance traveled by the thermistor over time τ; R – rocker arm length; n – the number of revolutions of the rocker arm.

Because S is also a function of air temperature, it must be determined for different rotational speeds at several temperatures and a training sample must be formed for the neural network in the form of a set of vectors $T_1, \Delta T_1 \rightarrow S^{T1}{}_{\Delta T1}$, where $T_1, \Delta T_1$ – air temperature and the obtained temperature change of the thermistor T for a given ratio n/τ, i.e. the number of revolutions of the EM per second, and $S^{T1}{}_{\Delta T1}$ – experimentally obtained by formula (3) "wind speed".

The error of measuring the wind speed by the proposed method depends on many variables – from errors in the identification of individual CF thermistors to the error in determining the time τ. Its analysis requires a separate study. Preliminary estimates have shown that the resulting error in measuring wind speed will not exceed 3%.

Conclusions

The conducted research gives grounds to consider the territory in the zone of influence of SE "Rozdil MCE »Sirka«", including on sites of storage of waste and products of their natural transformation, as perspective sites for construction of solar and wind power plants.

The proposed method of Ad-hoc wind speed measurement is based on widely available public equipment and requires minimal costs to implement. However, to ensure acceptable measurement accuracy, this method requires a significant amount of experimental research in tuning. Therefore, the method is helpful when creating a temporary meteorological network of anemometers for the study of, for example, air flows in complex rooms.

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Sustainable development – state and prospects (SDEV'2022)
Mirosław Borkowski, Oleksandr Moroz, Mykhailo Paslavskyi (red.)
Wydawnictwo GSW • Gdańsk 2023 • ISBN 978-83-66270-30-5

UDC 379.85

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Cultural heritage of ethnic minorities in the context of sustainable development of tourism

Abstract
The article describes theoretical foundations of the study of ethnic minorities' cultural heritage on the example of Vinnytsia Oblast in Ukraine. The attention is focused on the cultural heritage of the Polish ethnic minority, which is quite well preserved to this day. The historical preconditions for the formation and development of cultural heritage of ethnic minorities in the modern Vinnytsia Oblast are studied. According to the 2001 census, there are more than 100 ethnic minorities in Vinnytsia Oblast, representing almost 6% of the total population. The most numerous are Russian (3.83%) and Polish (0.22%) ethnic minorities. The Oblast has a rich historical and cultural heritage. Jewish and Polish minorities have the largest number of preserved cultural heritage objects of ethnic minorities, mostly sacred buildings and palaces. It was found that the main centers of cultural heritage of ethnic minorities of the Oblast are cities of Vinnytsia, Illintsi, Zhmerynka, Bar, Brailiv, Khmilnyk, Mogyliv-Podilsky, Sharhorod et al. A map of the geography of cultural heritage of ethnic minorities of Vinnytsia Oblast in the context of modern ethno-geographical relations is developed. It was found that the largest share of ethnic minorities is in the following areas with centers in the cities: Koziatyn, Bar, Tyvriv, Tulchyn, Gaisyn, Tomashpil, Bershad. The main types of preserved objects of ethnic minorities' cultural heritage of Vinnytsia Oblast are highlighted. The main preserved cultural heritage objects of the Polish ethnic minority are described. A number of problems of historical and cultural heritage of ethnic minorities of Vinnytsia Oblast were identified, in particular: violation of the connection between the number of minorities and the number of cultural heritage objects; unsatisfactory condition of certain cultural heritage objects; low level of their use for tourism purposes; use of the objects not for their functional purpose. In Ukraine, cultural heritage objects of ethnic minorities are often neglected and little known. At the same time, the cultural heritage of ethnic minorities can be the basis for the development of various types of tourism. A new tourist route is developed with the objects of historical and cultural heritage of the Polish minority of Vinnytsia Oblast and the corresponding map is created. Involving the cultural heritage of ethnic minorities in the tourism process will contribute to the sustainable development of territories, which involves solution economic, environmental and social issues, as well as preservation and promotion of historical and cultural objects.

Introduction

The global sustainable development goals, endorsed by world leaders, set important goals for humanity to help prosper and protect the planet. The successful implementation of these tasks and the achievement of sustainable development goals require coordination and pooling of efforts, interaction and vision of our common future. All this has one common basis – culture.

The formation of Ukraine as an independent state, its integration into the world community imposes on it the responsibility for the fate of the original historical relics of different times and peoples that are located on its territory and are an integral part of the world cultural treasury. The completeness and objectivity of the coverage of history depends on the preservation of monuments of different eras and periods. Attitude towards monuments is an indicator of the civilized society, understanding of deep tendencies in the development of culture.

Ukraine is a state whose cultural heritage, along with Ukrainians, was formed by representatives of other ethnic minorities, including Jews, Poles, Germans, Russians, Armenians, et al. (over 130 nationalities). Currently, most oblasts of Ukraine are monoethnic. According to the 2001 census, share of Ukrainians is 78% of the total population, and share of other ethnic minorities is 22% [8]. Each ethnic minority has its own unique historical and cultural heritage that needs to be protected. Ethnic minorities have distinctive ethnic, artistic, religious or linguistic characteristics; strive to preserve their ethnic identity, monuments, culture, traditions, religion, language [12].

Analysis of the literature

Issues on protection of cultural heritage of ethnic minorities are relevant in many countries around the world and are addressed at both international and national levels. Well-known international organizations dealing with these issues are: the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations World Tourism Organization (UNWTO), World Travel and Tourism Council, Organization of World Heritage Cities. The Ministry of Culture and Information Policy is the central executive body in the field of cultural heritage protection in Ukraine. There are also a number of public organizations at various levels, such as the Ukrainian Association of the Protection of Historical and Cultural Monuments. The need and obligation to preserve the historical and cultural heritage of ethnic minorities in Ukraine is regulated by a number of normative documents [15].

Popular in the world concept of multiculturalism aims to reduce contradictions between ethnic minorities, the interaction of different cultures, understanding and unification of society [7]. Multiculturalism is a modern policy of migrant states (for example, Canada, USA, Australia) on the management of cultural diversity and provides for the recognition of collective rights, support and development of ethnic minority cultures for the peaceful coexistence of different nationalities [1, 3]. Effective management of the historical and cultural heritage of ethnic minorities requires the cooperation of state and local authorities, society, scientific and other institutions [4, 5].

The preservation of cultural heritage contributes to sustainable development. This was declared in 2015 at the UN General Assembly, which adopted the "2030 Agenda for Sustainable Development" [13].

In Ukraine, cultural heritage objects of ethnic minorities are often neglected and little known. At the same time, the cultural heritage of ethnic minorities can be the basis for the development of various types of tourism, including ethnic, which may include: visits by tourists to their historical homeland; visiting settlements where traditions have been preserved, life of certain peoples; visiting museums, including open-air museums [2, 9].

Tourism is a priority object for the implementation of the principles of sustainable development, which implies the harmonious coexistence of the subjects of the tourism business, the environment, and society. Sustainable tourism was seen as the management of all resources in such a way that economic, social and aesthetic needs can be met while preserving the environment, cultural identity [16].

Tourism development should be based on the criterion of sustainability. It should be environmentally acceptable for a long period of time, economically beneficial, as well as morally and socially fair and equal in relation to local communities [11]. One of the principles of sustainable development of tourism in the social sphere is the respect and preservation of local cultures, traditional crafts, folklore, historical and cultural heritage.

Cultural heritage studies are carried out by R. Harrison, N. Ismail, T. Masron, A. Ahmad, L. Matlai, S. Zakharin, K. Polyvach et al. Problems of ethnic minorities are studied by M. Dnistrianskyi, I. Kresina, T. Katargina, L. Novikova, D. Tkachuk, E. Tkachenko et al. The issues of tourism development in Ukraine in the context of sustainable development are reflected in the studies of scientists V. Babarytska, O. Lyubitseva, T. Tkachenko, I. Smal, V. Smal, G. Zayachkovska et al.

Topicality

The study of the current state of the existing cultural heritage objects of ethnic minorities is especially important precisely because it will draw the attention of society to them, as well as develop measures for their preservation, restoration and promotion. Such studies are especially relevant for areas where many ethnic minorities live or have lived. Such is the Vinnytsia Oblast of Ukraine, where a large number of preserved cultural heritage objects of the Polish ethnic minority are concentrated.

The purpose of the article is the study of the Polish ethnic minority of the Vinnytsa Oblast, its cultural heritage and tourism potential. Tasks of the study: to analyze ethnic composition of the population of the Vinnytsia Oblast; to study the current state of the existing cultural heritage objects of the Polish ethnic minority; to identify areas (centers) with the maximum concentration of preserved objects of cultural heritage of the Polish ethnic minority; to reflect cartographically features of the placement of the cultural heritage of ethnic minorities in the Vinnytsia Oblast; to suggest ways of using the existing heritage in tourism.

Research results

The ethnocultural heritage of Vinnytsia Oblast is rich. This is due to the fact that people from different ethnic minorities lived here, leaving behind many monuments. However, as a result of the events of the Second World War, the population of certain ethnic minorities decreased significantly.

According to the last census, which took place in 2001, there are more than 100 ethnic minorities in Vinnytsia Oblast, which have formed more than 70 public associations, including Polish (26), Jewish (9), Azerbaijani (2), and Roma (4), Crimean Tatar (2), Czech (2). In addition, there are minorities of Belarusians, Armenians, Greeks, Georgians, Germans, Lithuanians et al. [10].

The ethnic composition of the population of Vinnytsia Oblast according to the 1939 and 2001 censuses is studied. The share of ethnic minorities in Vinnytsia Oblast in 1939 was 13.9%, and in 2001 – 5.81% of the total population. The largest in 2001 were the Russian (3.83%) and Polish (0.22%) minorities, and, according to 1939 data, the Jewish (6.04%) and Russian (4.5%) minorities. The geography of the cultural heritage of ethnic minorities and the number of preserved cultural heritage objects of Vinnytsia Oblast are shown in the Fig. 1.

In the 18th century the Jesuit order contributed to the spread of Polish colonization in Ukrainian lands. At that time, the density of compact living of Poles within Podillia was 6.4 inhabitants per 1 km^2, and in Bratslav – about 3.8 inhabitants per 1 km^2 [6]. Since then, as a result of assimilation processes and territorial and political changes, the number and share of ethnic Poles in the Vinnytsia Oblast has decreased significantly. According to the 2001 census, 3.794 thou ethnic Poles lived in Vinnytsia Oblast, which was only 0.2% of the total population. There are only a few cities and districts where the share of the Polish ethnic minority ranges from 1 to 0.2%: Koziatyn and Koziatyn district (1.0%), Khmilnyk (1.0%), Bar and Gnivan (0.6% each), Vinnytsia (0.5%), Ladyzhyn (0.4%), Barsky, Tyvrivsky and Khmilnytsky districts (0.3% each), Kalynivka (0.3%).

The largest ethnic community in terms of numbers (1.8 thou people) lives in the city of Vinnytsia. It is here that most of the sacred and cultural objects associated with the long-term presence of the Polish ethnic minority in Podillia are preserved. These include the Dominican Monastery (built in 1624), which was originally made of wood and rebuilt into a brick church in 1760. Now it is the Holy Transfiguration Cathedral. The Church of the Blessed Virgin Mary (1746) is a functioning church and belongs to the Capuchin Order. Jesuit Monastery (1611) – today the State Archives of Vinnytsia Oblast, the Museum of Local Lore and Art, as well as the Technical Lyceum function on the territory of the monastery. Pyatnychany Castle (built in the 18th century) is located within the city limits, the former village of Pyatnychany was once the property of the Grokholski family.

A significant number of cultural heritage objects of the Polish ethnic minority are located in such cities as Bar (ruins of Bar Castle, St. Anna's Church, Carmelite Monastery); Zhmerynka (Church of St. Oleksii); Tulchyn (Potocki Palace (18th century), Church of St. Stanislaus; Dominican Church (now Christ the Nativity Cathedral); Khmilnyk (Church of the Holy Trinity, 1603); Shargorod (Church of St. Florian, 1595).

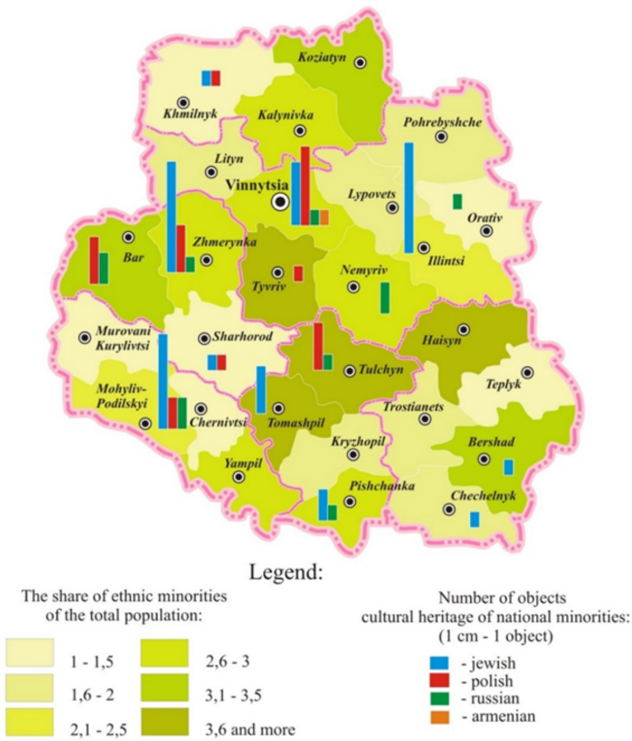

Fig. 1. Geography of the cultural heritage of ethnic minorities of the Vinnytsia Oblast in the context of modern ethno-geographical relations (developed by the authors)

Several palaces founded by Poles have survived in the Vinnytsia Oblast. In the village of Voronovytsia near Vinnytsia there is the Grokholski Palace, built by the Polish magnate Grokholsky (18th century), as well as the Church of Michael the Archangel (18th century). There is the palace of M. Chatsky in the village Serebryntsi, Mogyliv-Podilsky district, a monument of national importance, built in 1770-1780 by Mykhailo Chatsky. The Orlovski Palace-Estate in Severynivka, Zhmerynsky district, was built in the 19th century and has survived to the present day. The palace of Ihnati Vitoslavsky was built in the 17th century (Cherniatin village). Komari Palace in the village Murovani Kurylivtsi was built in 1805. Cherlenkivsky Castle was built in the 17th century (village Selyshche, Tyvriv district) – now the ruins of the building remain [14].

There are 26 Polish public organizations in the Oblast. The presence of such organizations can be an additional factor in the development of various types of ethnic tourism, in particular, the organization of ethno-festivals, historical and educational tours.

One of the effective ways to restore and popularize the preserved cultural heritage objects of the ethnic minorities of the Oblast, in particular, Polish one, is to include them in tourist routes. On their basis, it is possible to develop tourist programs or thematic tours with inclusion of certain types of preserved objects. We have developed and mapped such route with the most attractive cultural heritage objects of the Polish minority (Fig. 2).

Fig. 2. The proposed tourist route of the objects of cultural heritage of the Polish ethnic minority in the Vinnytsia Oblast (developed by the authors)

The route includes: Vinnytsia (Holy Transfiguration Cathedral, Church of the Holy Virgin Mary, Jesuit Monastery, Pyatnychansky Castle, Grokholski Palace) – Bar (ruins of the Bar Castle, church, monastery) – Zhmerynka (St. Oleksii Church) – Shargorod (Church of St. Florian) – Serebryntsi of Mogyliv-Podilsky district (Chatsky Palace) – Chornomyn, Pishchansky district (Chornomski Counts Palace) – Tulchyn (Pototski Palace, churches).

Discussion of results

Our study concerns the Vinnytsia Oblast. It is unique in the sense that it is monoethnic, but at the same time it was and is now inhabited by different ethnic minorities. We followed the historical preconditions of the development of ethnic minorities in the Oblast and identified numerous of them. We studied the cultural heritage objects of the surviving ethnic minorities in the Oblast and the problems of their development. Particular emphasis is placed on the cultural heritage of the Polish ethnic minority as one of the most numerous in the Oblast. The most attractive objects are identified and on their basis a tourist route is created, which in the future can be used by tourism operators to develop tourist programs. This route is intended for all interested, in particular Poles.

The development of ethnic tourism based on cultural heritage will help attract the attention of different ethnic groups to the problems of preserving this heritage, and therefore contribute to the sustainable development of the region. Such studies can be carried out both for other ethnic minorities and other regions. On this basis, it is possible later to develop comprehensive programs for the multicultural development of territories. But such studies need a field part. It is rather difficult to study the current state of cultural heritage objects on the basis of Internet data.

Conclusions

Vinnytsia Oblast has a rich historical and cultural heritage of ethnic minorities, in particular, Jews, Poles, Russians, etc. But to this day, the cultural heritage of the Polish ethnic group has been better preserved, which is a source of further social and spiritual development of the ethnically Polish population of the region and is of attractive importance for attracting tourists from other regions and countries.

The largest number of sacred and cultural objects associated with the long-term presence of the Polish ethnic minority in Podillia has been preserved in Vinnytsia. Other centers of concentration of the cultural heritage of ethnic Poles are the cities of Bar, Zhmerynka, Tulchyn, Khmilnyk, Shargorod.

One of the ways to preserve the cultural heritage of ethnic minorities is the development of tourist routes and their further implementation. The involvement of the cultural heritage of the Polish ethnic minority in the tourism process will contribute to the sustainable development of the territories, as it will activate the development of local communities, improve the well-being of the local population, create new jobs, help preserve historical and cultural objects, promote them, etc.

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Sustainable development – state and prospects (SDEV'2022)
Mirosław Borkowski, Oleksandr Moroz, Mykhailo Paslavskyi (red.)
Wydawnictwo GSW • Gdańsk 2023 • ISBN 978-83-66270-30-5

UDC 504.05

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Dynamics of desalinization of salinized soils in the areas of liquidated mining and chemical enterprises in the Pre-Carpathian region

Abstract
The article describes the ability of soil filtration under leaching conditions to be studied on rock samples of the gypsum-clay cap of the Stebnytskyi and Kalush-Holinsky potash deposits. The specific properties of saline clay soils containing a large amount of easily and moderately soluble salts, the main patterns of changes in these properties during soaking and flooding of territories are very important for the reasonable design of foundations and foundations of industrial and civil structures on saline soils, taking into account their possible watering by atmospheric precipitation, with soaking or flooding as a result of an accident or leaks from water supply networks, sewage, technological pipelines. Quantitative dependencies were established and experiments were conducted to develop the methodology and study the physical, strength, deformation, filtration and rheological properties of salted loams and clays. The chemical composition and mineralization of underground water were determined, the content of water-soluble salts in the soil and the physical properties of saline soils were determined. The module of general deformation for saline, poorly hydrated and water-saturated soils, and the nature of its change depending on humidity and the amount of easily soluble salts, were established. A special cycle of research on the compressibility of saline soils was conducted and their strength characteristics were determined. The mathematical model of the problem of calculating the concentration of salts in the liquid that is filtered is considered, and the changes in the specific volume of salts contained in the saline soil and the suffusion subsidence that occurs at the same time are calculated. The function distributions were obtained and the suffusion subsidence of the soil in time was determined for the natural stress state with film and dispersed salinity. Based on the results of the calculations, graphs of the kinetics of suffusion subsidence for film and dispersed salinization were constructed for weakly and strongly plastered saline soil.

Introduction

The features of soil filtration under desalinizing conditions were studied on samples of soils from the gypsum-clay cap of potash deposits in the Eastern Pre-Carpathian region. The studies were carried out on soil samples from the Stebnyk and Kalush-Golyn deposits. The study of filtration and desalinizing these soils is of great practical importance in assessing the mining conditions for the operation of potash deposits and the liquidation of mining and chemical enterprises.

According to the granulometric composition, the soils of the gypsum-clay cap are represented by silty loams (from light to heavy) and clays, often containing a significant amount of large fragments of the material. They are characterized by a brecciated composition, often penetrated by cracks,

The soils of the gypsum-clay cap are characterized by significant, and mixed salinity: the content of easily soluble salts ranges from 0.2 to 13%, gypsum – from 2 to 70%, carbonates – from 0.5 to 20%. The salinity increases with depth [1].

Analysis of the literature

The specific properties of saline clay soils containing a large amount of easily and moderately soluble salts: the main patterns of changes in these properties during wetting and flooding of territories are very important for the sound design of bases and foundations of industrial and civil structures on saline soils, taking into account the possible watering of them by atmospheric precipitation, during soaking or flooding as a result of an accident or leaks from water supply networks, sewerage, technological pipelines [2].

In the conditions of modern development of society, the problem of development and building-up of large land areas occupies a significant place. Strong competition, high building density and lack of land fund have led to the involvement in the construction of structurally unstable soils of the Kalush industrial district of Ivano-Frankivsk region.

Research results

To establish quantitative dependences, experiments were conducted to develop methods and study the physical, strength, deformation, filtration and rheological properties of saline loams and clays in laboratory conditions on samples taken in the areas of liquidated mining and chemical enterprises of the Pre-Carpathian region [3-5].

Soil samples were taken from the pits every 0.5 m in depth to the groundwater level. Samples below the groundwater level were taken to determine the chemical composition and mineralization of groundwater. The experiments were performed with multiple replicates. The reproducibility of the experiment was verified using the Cochran test [6].

The content of water-soluble salts in the soil was determined by identifying the dry residue of the aqueous extract. As shown by the study results (Table 1), the soils of the experimental plots are characterized by a high content of easily soluble salts, which allows them to be classified as excessively salinized. The dry salt residue was 7.8%.

The physical properties of saline soils were studied under laboratory conditions, taking into account the impact of salts. The density of water-saturated saline soils was determined by the cutting-ring method, and that of saline soils of a solid consistency was determined by the waxing method, the moisture content of saline soils was determined by the weight method, drying them in an oven at a temperature of 60-65°C to constant weight [10].

Table 1. Chemical composition of the salinized soils

Ca^{2+}	Mg^{2+}	$Na^{+}+K^{+}$	SO_4^{2-}	Cl^{-}	HCO_3^{-}
100	44.4	374.0	428	3.94	123
60	45.2	284.0	381	1.97	99
12	37.9	350.0	396	1.97	123
421	81.0	160.0	560	3.60	113
328	72.0	151.0	641	4.20	154
271	67.0	140.0	481	3.10	124

The density of soil particles containing easily and moderately soluble salts was determined taking into account the possibility of dissolving salts under vacuum in a neutral liquid (dehydrated kerosene, toluene).

The change in the particle size distribution of saline soils in the process of salt leaching was established without washing and with salt washing [2, 9].

The experimental studies have shown that with an increase in the content of easily soluble salts, the density of particles of saline clay soil decreases (Table 2).

Table 2. Relationship between salt content and soil particle density

Salt content, %	1-3	3-5	5-8
Density of soil particles, g/cm^3	2.69-2.67	2.67-2.65	2.65-2.6

The density of saline clay soil, depending on the composition of easily soluble salts, varied between 1.80 and 1.86 g/cm^3 and did not depend on their quantity. Thus, density is not an indicator of the specific properties of saline soils.

In the presence of a significant amount of easily soluble salts, the density of soil particles is 1.40-1.50 g/cm^3 and can serve as an indirect characteristic of the possibility of the development of suffusive processes (Table 3).

The moisture content of saline clay soils, as the studies have shown, is not a characteristic property for predicting suffusive soil subsidence.

The plasticity limit of soils is an important characteristic by which the type of soil is identified.

However, the existing method for determining the limits of plasticity is unacceptable for saline clay soils, since with an increase in the content of sulfate salts, the moisture content at the liquid limit increases, and with the presence of chloride salts in soils, the moisture content at the soil rolling limit turns out to be lower and the moisture content at the liquid limit decreases significantly (compared to the desalinized clay sample) (Fig. 1).

Table 3. Physical characteristics of saline soils

Soil	Sample No.	Physical characteristics of saline soils						
		ρ	γ	w	w_z	ρ_d	s_r	e
Loam	1	1.80	2.76	0.28	0.02	1.40	0.98	0.80
	2	1.82	2.77	0.28	0.02	1.41	0.97	0.84
	3	1.86	2.77	0.29	0.02	1.44	0.93	0.87
Clay	4	1.90	2.80	0.29	0.02	1.47	0.91	0.91
	5	1.93	2.81	0.29	0.02	1.48	0.89	0.94
	6	1.97	2.81	0.30	0.02	1.50	0.87	0.97

It is also unacceptable to determine the granulometric composition of saline clayey soils by conventional methods. Special studies were carried out on soils of sulfate and chloride-sulfate types of salinization of varying degrees.

The granulometric composition (particle size distribution) was determined according to the generally accepted method [11] before and after leaching.

As the study results showed, the amount of clay particles (0.005 mm) increased by 20-28% after salt leaching.This is due to the fact that in the presence of salts in the porous solution, individual clay particles stick together in groups (conglomerates), and when the concentration of the porous solution decreases, these groups disintegrate.

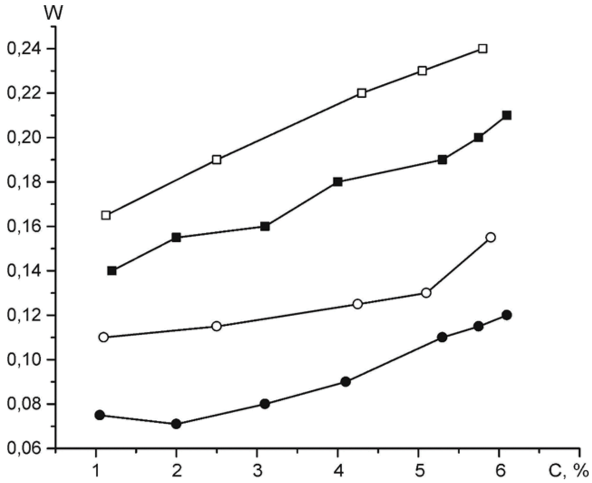
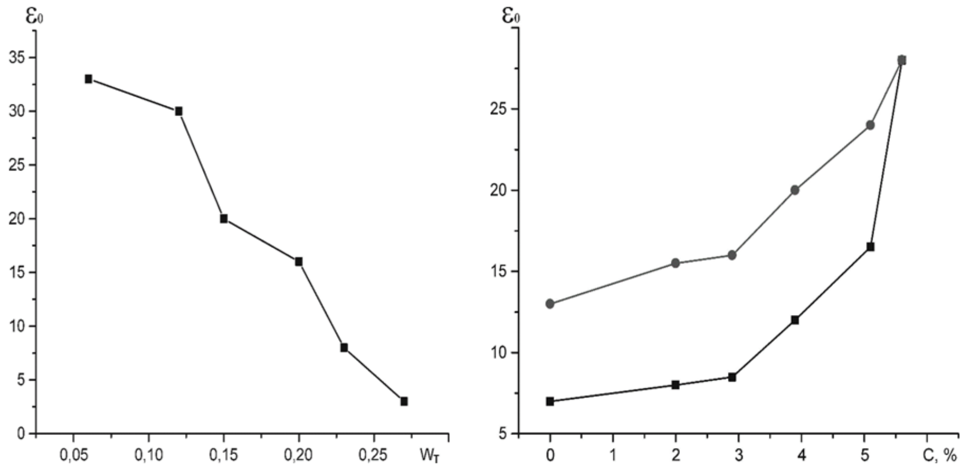


Fig. 1. Change in the plasticity limits of clay soils at: (●, ○) – sulfate salinity; (■, □) – chloride-sulfate salinity; (●, ■) – the lower limit of plasticity; (○, □) – the upper limit of plasticity

Thus, the determination of particle size distribution by using the generally accepted methods can lead to errors. It was necessary to establish the total deformation modulus for saline low-moistened and water-saturated soils and the nature of its change depending on the moisture content and the amount of easily soluble salts.

Soil compressibility increases with increasing moisture content (Fig. 2). The study results showed that saline soils with natural moisture content have a very high total deformation modulus, which indicates the impossibility of the development of soil subsidence phenomena.



(a) (b)

Fig. 2. Change in the total deformation modulus E_0 of saline soils with increasing moisture content (a) and leaching of salts (b)

Thus, for some soil samples, the modulus of total deformation decreased from 34.0 to 4.0 MPa when the moisture content at the rolling limit changed to the moisture content at the liquid limit.

With a further increase in moisture content up to a double value of moisture content at the rolling limit, the deformation modulus decreased to 2.4 MPa.

A special cycle of studies of the compressibility of saline soils was carried out on identical clay soil samples: one sample was placed in a compression device (the experiments were carried out under water), and the other one was placed in a compression-filtration device.

Degassed distilled water was passed through the sample in the compression-filtration device for one day at t = 60ºC and pressure gradient I = 8-10.

Filtration took place through the sample in an upward flow from bottom to top. The infiltrate was collected in a beaker to determine the chemical composition during the experiment. Then, identical samples in different devices were loaded according to the same scheme at a pressure of 0.01, 0.02, 0.03, 0.05, 0.075, 0.10, 0.15, 0.20, 0.25, 0.30 MPa [7].

As the results of the studies showed (Fig. 3), after the removal of easily soluble salts, the compressibility of soils increased significantly, and the deformation modulus decreased by 10-75% compared with the results of studies in the compression devices for the same pressure ranges.

Based on the studies conducted, it can be concluded that the compressibility of clay soils containing a large amount of easily soluble salts significantly depends on the conditions for salt removal.

If, during the construction process, saline clay soils of the base are prone to significant watering, as a result of which their desalinization will occur, then, when calculating soil subsidence, the modulus of total deformation obtained after preliminary soil desalting should be used.

If saline clay soils have low permeability, and, according to the technological scheme of construction of the structure, watering is not provided, then the modulus of total deformation should be determined on compression devices after the soils are saturated with water [8].

Usually, in the calculations of foundations, the characteristics obtained in laboratory studies of soils by the method of slow consolidated shear are used.

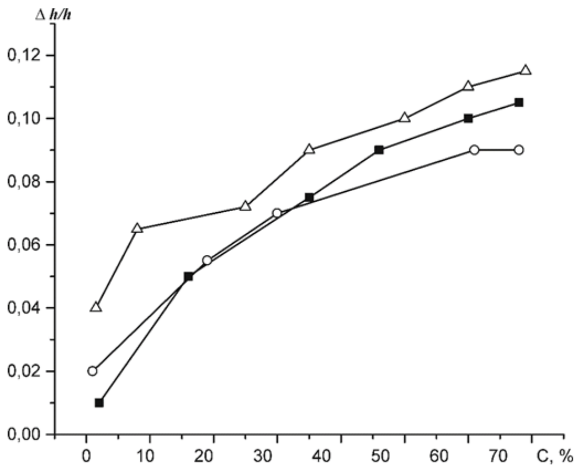


Fig. 3. Compressibility of clay soil samples containing easily soluble salts at p = 0.1 MPa: (◀) – loam; (●, ■) – gypsum loam

However, such calculations are inaccurate, and sometimes cause the loss of stability of foundations on saline soils, both during the construction process and during the operation of buildings and structures.

To determine the strength characteristics, special laboratory studies were carried out on samples of saline soils from the base of the experimental site on the device of single-plane soil slip using the method of slow consolidated and rapid soil slip at natural porosity and after preliminary compaction at a pressure of 0.10, 0.20, 0.30 MPa.

Soil samples of low moisture content and after artificial water saturation were studied. A total of 76 samples were examined using different methods (Fig. 4).

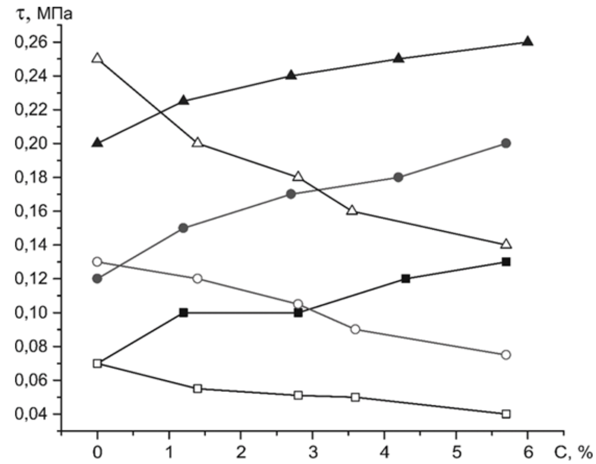


Fig. 4. Dependences of the strength of saline clay soils: 0.1 MPa (■); 0.2 MPa (●); 0.3 MPa (◀); natural moisture content – flooded symbols; water saturation – not flooded symbols

As a result of the studies it was found that saline clay soils, both low-moistened and water-saturated, with a change in vertical pressure from 0.025 to 0.5 MPa have constant angles of internal friction φ and adhesion C. No significant difference was found when comparing the results of studies of saline clay soils (both low-moistened and water-saturated) with macroporous low-moistured loess loams.

In order to reveal the effect of easily soluble salts on the strength characteristics of the soil, six to ten identical samples for shear device rings with an area $F = 40$ cm^2 were cut from a large monolith of saline clay soil. Half of the samples were placed in a compression-filtration device, through which, at a certain pressure of 0.025, 0.05, 0.075, 0.1 MPa, tap or distilled water was passed to wash out easily soluble salts.The amount of salts removed was determined by analysis of the infiltrate extract. After that, the desalinized clay samples were tested on the same instruments and according to the same procedure as the soils of natural salinity.

In all series of the experiments, the strength characteristics of desalinized soils turned out to be significantly lower (by 10%) compared to the results of studies of identical samples of natural salinity. Soil adhesion is especially reduced. Thus, in the study by the method of rapid soil slip. adhesion was 0.048 MPa, and after pre-desalinization – 0.010 MPa. According to the method of slow consolidated shear for saline soils, the adhesion was 0.036 MPa, and after salinization – 0.010 MPa.

Influence of soil salinization on resistance under long-term static load

Environmental safety of the regions is one of the most important problems at the present stage of society development. The deterioration of the ecological state of the environment and the deterioration of the health of the population living in these areas determines the need to study environmental hazards and risks.

Strong competition, high building system density and insufficient land resources have led to the involvement of structurally unstable soils in the construction.

In the Kalush industrial district of Ivano-Frankivsk region, large areas are occupied by saline soils belonging to the region of the liquidated mining and chemical enterprises of the Pre-Carpathian region.

Today, the problem of protection against destruction of structures of civil and industrial construction is one of the most important ones. When designing structures that are located in the zone of harmful effects of mining workings, it is necessary to take into account the current State Building Regulations of Ukraine and international standards used in the construction of structures [12].

When choosing a construction site, it is necessary to take into account that on it:

- there are no deposits of potassium salts;
- there are non-industrial reserves;
- the deposits are depleted, the process of deformation of the soil surface is completed, and after stabilization of the deformation, the possibility of the appearance of craters and dips is excluded;
- mine production is expected after completion of the depreciation period of the structure.

The study of foreign experience makes it possible to predict the stability of the foundations of buildings constructed in saline areas.

The subsidence of clay soils is characterized by a number of indicators: subsidence limit, density of the soil skeleton at the subsidence boundary, the magnitude of the relative linear and volumetric subsidence.

Soil subsidence is often determined by calculation, using either the method of M. Ya. Denisov, according to which the volumetric subsidence of the soil is calculated by the formula:

$$V = \left(1 - \frac{\rho_d^b}{\rho_d^c}\right) \cdot 100, \tag{1}$$

where: $\rho^b{}_d$ – moisture content of the moist soil skeleton; $\rho^c{}_d$ – moisture content ofthe dry soil skeleton. Or the method of E.M. Sergeev, according to which the volumetric subsidence of completely water-saturated soil is described by the equation:

$$V = V_C (1 + \beta_V W), \tag{2}$$

where: V – soil volume at moisture content W; V_C – volume of dry soil; β_V – the coefficient of volumetric subsidence which is equal to the relative increase in volume with a change in moisture content per unit:

$$\beta_V = \frac{V_1 - V_2}{V_2 W_1 - V_1 W_2}, \tag{3}$$

where: V_1 and V_2 – the values of the volume of soil at moisture content W_1 and W_2, respectively [4, 10].

The limit of soil subsidence can be calculated from the ratio:

$$W_s = \frac{e_s \rho}{\rho_s}, \tag{4}$$

where: e_S – the soil porosity coefficient at the soil subsidence limit; ρ – density of moist soil; ρ_S – density of the stiff part of the soil.

At present, in the study of soil mechanics there is no rigorous mathematical formulation of the problem of stress-strain state of the mass of water-saturated saline soil and changes in this state taking into account the processes of mass transfer and mass exchange between soil components.This significantly slows down the further development of methods for calculating the foundations, located on saline soils.

The presence of salts of different quantitative composition in soils affects the deformation parameters of the soils. When saline soils are moistened, the salts contained in them are dissolved and removed, and, accordingly, the porosity of the soil increases. An increase in the porosity of saline soils during moistening, in turn, leads to suffusive soil subsidence [12].

For subsidence of a homogeneous layer of soil in the direction of the *X* axis, we take the formula (5):

$$S(t) = \int_{h_1}^{h_2} \alpha_0 (\sigma - \overline{\sigma_0})^{\nu_0} \frac{\xi_0 - \xi(t)}{\xi_0} dx, \tag{5}$$

where: h_1, h_2 – respectively, the upper and lower limits of the area of suffusive subsidence; $\sigma = \gamma_0 x$ – change in compaction load by depth under natural stress conditions, MPa; γ_0 – specific weight of soil in water-saturated condition, N/cm^3; α_0, ν_0 – nonlinear deformation parameters that are constant for a homogeneous soil thickness; ξ(t) – function of distribution of specific volume of salts, in fractions of units; $\overline{\sigma}_0$ – the minimum pressure at which suffusivesoil subsidence occurs, MPa [12].

In the general case, the law of change in the specific volume of soluble salts in the soil with depth and over time is described by the system of equations (6):

$$\begin{cases} Dm_0 \dfrac{\partial^2 C}{\partial x^2} - \nu \dfrac{\partial C}{\partial x} - \delta \dfrac{\partial \xi}{\partial t} = m_0 \dfrac{\partial C}{\partial t}; \\ \dfrac{\partial \xi}{\partial t} = -\dfrac{\gamma}{\delta}(C_m - C)\xi^k \end{cases}, \tag{6}$$

where: D – coefficient of convective diffusion, cm^2/s; C – concentration of salts in the liquid, g/cm^3; ξ – specific volume of salts in the soil, in fractions of units; C_m – concentration of water saturation with salts of a given composition, g/cm^3; γ – generalized salt recovery coefficient, c^{-1}; m_0 – soil porosity; ν – groundwater filtration rate, cm/s; δ – density of salts, g/cm^3; k – salinity coefficient.

In the system (1.6) k takes the values 0, 0.5, 1. When $k = 0$, we get the case of film salinization of the soil; at $k = 0.5$ or 1 – the case of volumetric (dispersed) salinization of the soil [3].

Let us consider a mathematical model of the problem of calculating the concentration of salts in a filtered liquid and calculating the change in the specific volume of salts contained in saline soil and the suffusive subsidence that occurs in this case.

To solve this problem, the system (1.6) is used with the following initial and boundary conditions (7):

$$\begin{cases} C(x,0) = C_H \\ \xi(x,0) = \xi_0 \end{cases},$$

$$\begin{cases} \dfrac{\partial C(0,t)}{\partial x} = \dfrac{v}{m_0 D}(C(0,t) - C_0) \\ \dfrac{\partial C(l,t)}{\partial x} = 0 \end{cases}, \tag{7}$$

where: C_H – uniform distribution of the concentration of salts in the liquid at the initial moment of time over the thickness of the soil, g/cm^3; C_0 – concentration of salts in the input section of the soil, g/cm^3; ξ_0 – uniform distribution of the specific volume of salts in the soil at the initial moment of time, in fractions of units; l – soil thickness, cm [13].

Let us solve system (6) with initial and boundary conditions (7) using the finite difference method.

Let us consider the system (6) at $k = 0$ and $v = const$. This is a case of film salinization of the soil. This problem is reduced to solving a system of differential equations:

$$\begin{cases} \dfrac{\partial C}{\partial \bar{t}} = \dfrac{1}{Pe}\dfrac{\partial^2 C}{\partial \bar{x}} - \dfrac{\partial C}{\partial \bar{x}} + N\left(C_m - C\right) \\ \dfrac{\partial \xi}{\partial \bar{t}} = -\dfrac{1}{\delta} N(C_m - C) \end{cases} \tag{8}$$

with initial and boundary conditions (9),

$$\begin{cases} C\left(\bar{x},0\right) = C_H \\ \xi\left(\bar{x},0\right) = \xi_0 \end{cases},$$

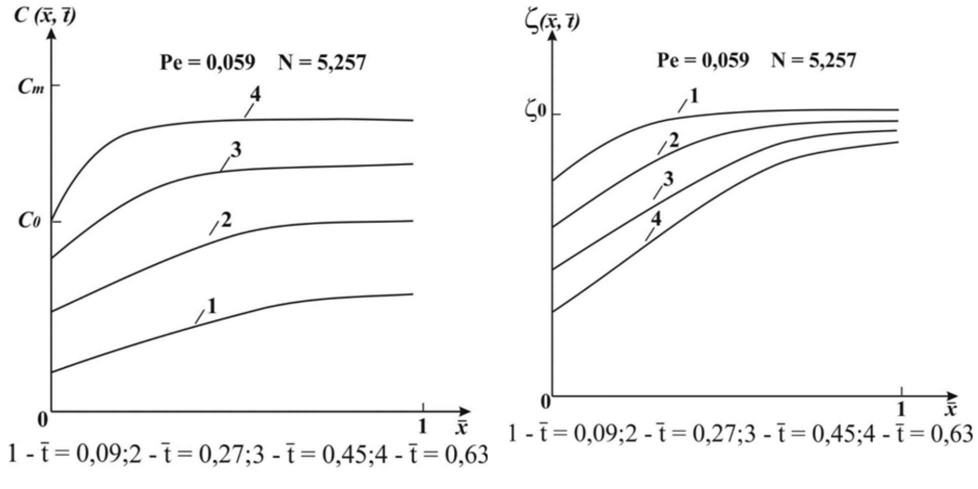
$$\begin{cases} \dfrac{\partial C(0,\bar{t})}{\partial \bar{x}} = Pe(C(0,\bar{t}) - C_0) \\ \dfrac{\partial C(l,\bar{t})}{\partial \bar{x}} = 0 \end{cases} \tag{9}$$

where: $\bar{x} = x/l$ – dimensionless coordinate; $\bar{t} = vt/m_0 l$ – dimensionless time; $Pe = vl/m_0 D$ – Peclet criterion; $N = m_0 \gamma l/v$ – dissolution criterion.

Thus, problem (8)-(9) will depend only on two dimensionless criteria *Pe* and *N*. The following data were used in the calculations: C_m = 0.026 g/cm^3; C_0 = 0.026 g/cm^3; C_H = 0.08 g/cm^3. Based on the results of calculations, the dependences of the salt concentration in the liquid (Fig. 5a) and the specific salt content on the thickness of the soil over time (Fig. 5b) were obtained.

Using the obtained distributions of the function $\xi(x,t)$, it is possible to determine the suffusive subsidence of the soil in time for the natural stress state in the case of film and dispersed salinity according to formula (5).

The calculations were performed for two typical cases of gypsum saline soil A = 10% (slightly gypsum saline) and A = 40% (strongly gypsum saline soil). For A = 10% we have the following data: $\bar{\sigma}_0$ = 0.038 MPa, Cm = 0.026g/cm^3, γ_0 = 0.015 N/cm^3, C_0 = 0 g/cm^3, γ = 0.001 c^{-1}, m_0 =0.6, v =55 cm/day, ξ0 = 0.6, $\dot{}$ D = 0.21 cm^2/sec, h = 10 cm, δ = 2.35 g/cm^3, v_0 = 1, a_0 = 0.075 MPa^{-1}.



(a) (b)

Fig. 5. The dependence of the concentration of salts in the liquid (a); and their specific volume in the soil (b)

For strongly gypsum saline soil, the non-linear compressibility coefficient is a_0 = 0.38 MPa^{-1}. According to the calculation results, graphs of the suffusive subsidence kinetics for film and dispersed salinization for slightly (Fig. 6a) and strongly gypsum saline soil (Fig. 6b) were plotted.

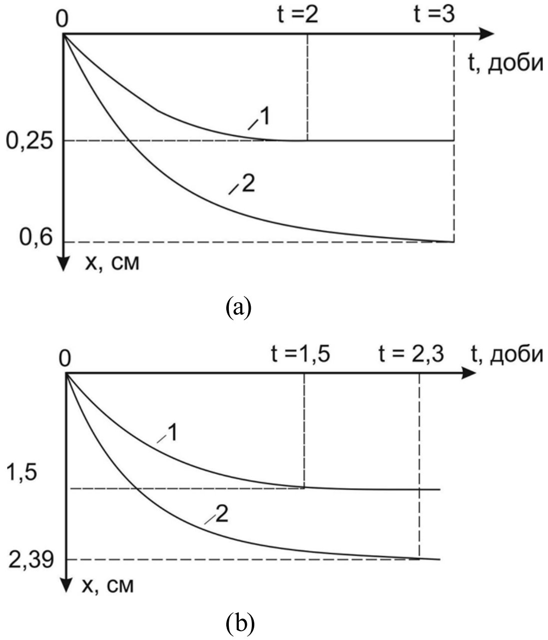


Fig. 6. Curves of suffusive subsidence: (a) for slightly gypsum saline soil; (b) for strongly gypsum saline soil; 1 – film salinization; 2 – dispersed salinization

As can be seen from the above dependences, slightly gypsum soils give smaller deformations compared to strongly gypsum soils. Similarly, strongly gypsum soils are characterized by relatively rapid stabilization of deformation, at which the process of suffusive subsidence stops.

These studies were performed for saline gypsum soils of the gypsum-clay cap of the Stebnyk deposit which is a kind of protector of clay saline soils from the penetration of fresh water [14, 15].

However, in general, the obtained dependences can be used for soils of the Kalush industrial area after minor adaptation and experimental verification in the field, because the soils that occur in these deposits are similar in structure.

Conclusions

1. It has been established that the strength characteristics of saline soils are on average 10% lower than those for non-saline soils, however, the adhesion indices decrease from 3.6 to 4.8 times.
2. The nature and causes of soil subsidence in the areas of liquidated mining and chemical enterprises of the Pre-Carpathian region have beenidentified. Based on the results of calculations, the dependences of the concentration of salts in

the liquid and the specific volume of salts on the thickness of the soil over time for cases of dispersed and film salinization are obtained.

3. Kinetic curves of suffusive subsidence for dispersed and film types of salinization are constructed, the use of which will make it possible to predict and control subsidence of saline soils of technogenic-loaded territories.The relationship between the level of dispersion of salts and the rate of their leaching has been revealed and it is shown that, in general, the rate of dissolution is proportional to the total surface area of the “salt-solvent” phase interface.

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Sustainable development – state and prospects (SDEV'2022)
Mirosław Borkowski, Oleksandr Moroz, Mykhailo Paslavskyi (red.)
Wydawnictwo GSW • Gdańsk 2023 • ISBN 978-83-66270-30-5

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Ecological safety of water bodies of Prykarpattia mining district

Abstract
The raw material base of Ukraine is concentrated in Prykarpattia. Development and processing of potash ores is accompanied by a significant impact on the environment. One of the features of the development of potash ores is the relatively low content of useful components and, as a consequence, a large amount of waste during their processing and obtaining the final product – mineral fertilizers. The emergency situation in the territory of Kalush mining district has been developing for many years due to economic activities on the extraction of potassium salts, which was carried out without effective technical and environmental measures. Potassium wastes deposited on the earth's surface are an unlimited source of salt pollution of environmental components. The main pollutants are chlorides, which are subject to wind scattering, diffusion and filtration migration, saline the geological environment. The activity of potash enterprises has a particularly negative effect on the hydrochemical regime of surface and groundwater. Salinization areas are expanding, mainly in the direction of groundwater flow and existing water intakes, which are located near the sources of pollution. The salinization of groundwater is facilitated by the processes of subsidence and deformation of the earth's surface over the workings. Sedimentation of the earth's surface is accompanied by landslides and cracks, as well as changes in engineering and geological properties of rocks. Self-flooding of the Dombrovsky salt quarry, erosion of salt heaps by atmospheric precipitation, overflow of tailings No. 2, spread of halos of salinization of Quaternary aquifer waters and danger of sharp deterioration of water quality in urban water intake, development of salt karst and subsidence buildings and residential buildings – this is the list that accurately describes the most important problems of the Kalush mining district. These problems are also of concern to the international community, as there is a risk of pollution of the Dniester River, which is a transboundary waterway. The most unprotected from the effects of brine are the rivers Limnytsia, Sivka, Dniester and groundwater, which are sources of drinking water. Exceedances of the maximum concentration limit of pollutants in these rivers were revealed, in particular, the largest exceedances are in the control area of the village Voynyliv, Sivka river, the mouth of the Sivka river and on the control line of the village Sivka-Voynyliv, Dniester River. Due to insufficient funding for environmental and technological measures, their unsatisfactory scientific and technical coordination, lack of monitoring system in the predominant focus on eliminating the already manifested negative consequences, the level of safety in the Kalush mining region has a steady tendency to deteriorate and formation of a cross-border emergency. Given the growing volume of brine in quarries and tailings, increasing the number of failure funnels and subsidence of the earth's surface is important conservation, reclamation or continuation of quarries in compliance with the requirements and introduction of new technologies and low-waste production. The developed recommendations to reduce the negative impact of the Dombrovsky quarry and its components on the environment, in particular on water bodies – groundwater, rivers Limnytsia, Sivka and with their proper and timely implementation will minimize the negative impact on the environment.

Introduction

The raw material base of Ukraine is concentrated in Prykarpattia. The Carpathian salt basin stretches in a strip 280 km long and 20-30 km wide from Poland to Romania.

Reserves of potash ores of explored and searched areas amount to more than 7.2 billion tons. Carpathian potassium ores are polymineral, containing more than 20 types of chloride, chloride-sulfate minerals of potassium, sodium, magnesium and calcium. In addition, they contain liquid and low-clarke elements, enriching which can be obtained with fertilizers containing trace elements in accordance with consumer requirements. On the basis of potassium ores of Prykarpattia, the mineral fertilizer kainite natural (K_2O – 9%, MgO – 5%, sulfur – 6%, sodium – 14%), which has been used in agriculture for over a century, is crushed and ground.

Development and processing of potash ores is accompanied by a significant impact on the environment. As a result of mining and processing works, volumetric heaps, dumps, subsidence are formed, which is a relief-forming factor. This leads to a partial redistribution of the hydro network, local changes in wind roses, climate, as well as the regime and chemical composition of groundwater. Burning of heaps, their wind and water erosion contribute to the pollution of the atmosphere, landscapes, surface and groundwater, which leads to large-scale rejection of productive lands.

Analysis of the literature

The strongest man-made impact on the environment is exerted by mining production. But in different regions of Ukraine the nature and degree of man-made loads on the environment, and consequently its transformation, are not the same and depend mainly on the scale of deposits, and accordingly, the scale of rock mass extracted and processed; chemical and mineral composition of the mining mass; technologies of enrichment and processing of minerals.

The negative consequences of man-made loads on the environment from the activities of mining industries in Ukraine are described in publications [1-4].

In addition, the results of research on environmental protection in mining regions are presented in the works of O.M. Adamenko [5, 6], G.I. Rudka [7], L.Ya. Poberezhna [8], O.R. Manyuka, Ya.M. Semchuk [9, 10] and others. Most of them are devoted to establishing the extent of surface and groundwater pollution in the development of ore, oil and gas fields. A small number of publications deal with the study of the impact of sources of pollution of potash production on the environment [11-17].

Topicality

The main problem of technogenic and ecological nature in the territory of Prykarpattia is the elimination of the consequences of the ecological emergency situation that has developed after the cessation of production activities of potash fertilizers in Kalush.

Problems related to the deterioration of man-caused environmental conditions in the Kalush mining area have existed for a long time, but especially exacerbated after the cessation of production of potash and magnesium production, as well as the operation of mining sites (mines, quarries) Kalush-Golinsky potassium salt deposits. With the sudden shutdown of the production complex, measures were taken to keep large mining facilities in a safe condition. Monitoring of changes in the geological environment within the location of these objects and the area of their potential negative impact is sporadic and fragmentary.

The main objects that have a negative impact on the environment and safety of living in the Kalush mining and industrial complex are:

1. Dombrovsky quarry: until 2008 it was the only open pit quarry in the world. 50.1 million m^3 of rock mass were extracted, residual balance reserves 32 million tons. The quarry is filled with brine (up to the average mark of the sole of the water horizon 0.55 m). The catchment area is 376 hectares. The inflow of water into the quarry is 2.5-2.7 million m^3 per year. The threat is the complete flooding of the quarry and the ingress of brine into the Dniester river basin.
2. Tail storage No. 1: area of 54 ha, halite salt-containing waste with a volume of 12-14 million m^3. The facility salinizes groundwater.
3. Tail Reservoir No. 2: area of 48 ha, filled with waste volume of 9.4 million m^3, of which solid phase 8 million m^3, threat – salinization of underground aquifers, the presence of karst cavities in the body of the dam, the threat of breakthrough and brine in the Dniester.
4. Salt dumps: No. 1 – area of 48 ha, 11.3 million m^3 of overburden salt-containing rocks, heap height 55 m; No. 4 – area of 39 ha, 7.4 million m^3 of overburden salt-bearing rocks, dump height of 30 m, both objects are saline underground water horizons.
5. Residual impact of the former toxic waste landfill of Oriana-Galev LLC. During 2010-2013, 29,431 thousand tons of waste containing hexachlorobenzene were exported outside the region. There is a risk of contamination of groundwater aquifers by decomposition products of hexachlorobenzene.
6. Subsidence of the earth's surface over the former mine workings of the Kalush, Golin and Novo-Golin mines is projected. 6. This is possible in residential areas with a population of about 4,500 people and industrial facilities.

Research results

Self-flooding of the Dombrovsky salt quarry, erosion of salt heaps by atmospheric precipitation, overflow of tailings No. 2, spread of halos of salinization of Quaternary aquifer waters and danger of sharp deterioration of water quality in urban water intake, development of salt karst and subsidence buildings and residential buildings – this is the list that accurately describes the most important problems of the Kalush mining district.

In this list, the problem of deterioration of groundwater and surface water due to saline infiltrates from salt dumps and tailings is one of the most important. In view of this, it is possible to assess the real ecological state on the basis of complex geochemical studies of river runoff from the zone of influence of the Kalush-Golinsky deposit. To do this, the main watercourses were tested and changes in their chemical composition were analyzed.

Fresh groundwater in the Carpathians may become salty through the Dombrovsky quarry. If this happens, the quarry will pollute the Sivka River, which flows into the Dniester River, which in turn will disperse the contaminated water to other countries.

After the quarry stopped, the pumping station, which pumped surface water from the drainage trench, also stopped, as a result of which the quarry began to be filled with water, as a result of which potassium salts began to dissolve. According to research, mineralization on the surface is about 10 mg/l, and at the bottom of the quarry reaches 400 mg/l.

Another problem of the Dombrovsky quarry is water erosion, which formed from the northern part of the quarry. The Sivka River also flows from this side, which drains the quarry and fills it with water. In 2020, during a flood in the Ivano-Frankivsk region, the dam of the Sivka River broke and part of the water fell into the quarry across the north side, according to experts, because it once began to build a quarry directly in the bed of the Sivka, and the river itself was artificially diverted, and it is during these 30-40 years that the river begins to return to its course. And now the fresh waters of Sivka are replenishing the salt basin of the quarry and, accordingly, the level will increase catastrophically, which will accelerate the inevitability that this salt water will flow into the Sivka River and continue to have a transboundary impact.

Tailings with waste from potash production also pose a threat of soil and surface water pollution. The first tailings pond, with an area of 54 hectares, holds about 4 million m^3 of waste. In 1993, reclamation was started on it, but it was not completed completely, as a result of which saline solutions, so-called merabilites, are washed out of the tailings due to atmospheric precipitation.

As a result, after the accumulation of large amounts of liquid and solid sludge on the surface and the development of rock shifts as a result of deformation of protective pillars began to threaten the destruction of protective dams, important engineering structures (mine buildings, roads, etc.) with the risk of catastrophic toxic brine discharges into the Dniester.

Emissions of large amounts of highly mineralized toxic effluents can be a factor in the long-term complication of drinking water supply in cities and towns of Ukraine and Moldova.

Changes in the engineering and ecological state of the geological environment in the area of influence of the Kalush Salt Mine can be considered critical, approaching catastrophic risks both under the influence of their own factors (subsidence, deformation of protective dams, etc.) and due to adverse effects of abnormal hydrometeorological conditions, increased precipitation) and local and transit earthquakes.

Flooding of the Dombrovsky quarry, soluble salts are washed out of salt dumps, tailings and accumulating tanks, which penetrate into the aquifer under the influence of atmospheric precipitation, pollute water arteries and then are transported by underground streams in the south-eastern direction Kalush. Above the former mine workings of the Kalush, Golin and Novo-Golin mines, the earth's surface subsides with the formation of dips and the outpouring of saline solutions.

Flooding of the Dombrovsky quarry and leaching of soluble salts sharply increases the load on the hydrosphere of the territory far below the direction of regional runoff and significantly exacerbates the environmental problems of Kalush and Halych districts. Drinking water intakes in the city of Kalush, Kalush and Halych districts, and possible pollution of the Dniester River with salts and carcinogens may be lost. It should be noted that the Dniester flows through the territory of 7 regions of Ukraine and the Republic of Moldova and is a source of drinking water supply for more than 10 million people.

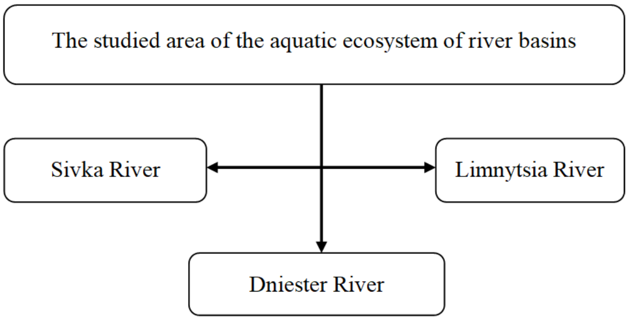

Fig. 1. Scheme of interdependence of structural units of the river system of the Dniester basin

Analysis of water samples from observation posts located on the Sivka River (observation post No. 1 – Voynyliv village, observation post No. 2 – Sivka River mouth), Dniester River (observation post No. 3 – Sivka-Voinyliv village, observation post No. 4 – Perlivtsi village, observation post No. 5 – Halych, observation post No. 6 – Ustechko village), and Limnytsia River (observation post No. 7 – Vistkova village) demonstrates that in almost all control lines there is a tendency to increase in pollutants, which in turn indicates that the process of loading the hydrosphere is gaining momentum.

Table 1. Comparative table of pollutants in the analyzed controls

Indicator	**MPC**	**Observation posts**						
		No. 1	**No. 2**	**No. 3**	**No. 4**	**No. 5**	**No. 6**	**No. 7**
Biochemical oxygen demand, mg O_2/dm^3	2.25	3.27/ 3.2^{*}/ 3.3^{**}	2.9/ 3.2^{*}/ 3.2^{**}	2.1/ 3.1^{*}/ 2.5^{**}	2.1/ 2.8^{*}/ 2.8^{**}	2.3/ 2.6^{*}/ 2.8^{**}	2.8/ 3.3^{*}/ 3.4^{**}	1.65/ 2^{*}/ 1.6^{**}
Suspended substances, mg/dm^3	<0.75	18/ 18.5^{*}/ 31.2^{**}	17/ 36.7^{*}/ 16.5^{**}	13.2/ 17.5^{*}/ 25.5^{**}	14.5/ 15.2^{*}/ 16.5^{**}	9.2/ 11.5^{*}/ 11.5^{**}	12.5/ 14.5^{*}/ 14.7^{**}	7/ 6.5^{*}/ 7.5^{**}

Indicator	MPC	Observation posts						
		No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
Mineralization, mg/dm^3	1000	761/ 1040*/ 881**	743/ 868.2*/ 972**	328/ 422.5*/ 376**	408/ 406.5*/ 373**	260/ 292.2*/ 344**	313/ 428.5*/ 393**	149/ 198*/ 222**
Sulfate ions, mg/dm^3	100	117.5/ 152.7*/ 158**	117.5/ 140.5*/ 187**	43.7/ 51.2*/ 47.7**	86/ 83.5*/ 62.7**	54.2/ 57.5*/ 60.5**	51.5/ 90.2*/ 71.5**	28/ 42.5*/ 35**
Chloride ions, mg/dm^3	300	260.5/ 383.5*/ 339.2**	254.2/ 319.7*/ 334.2**	23.5/ 41*/ 43.2**	34.5/ 34.7*/ 45**	21.7/ 22.5*/ 37.7**	24.7/ 29.2*/ 29.2**	8.57/ 13.9*/ 22.5**
Ammonium ions, mg/dm^3	–	0.46/ 0.61*/ 0.82**	0.4/ 0.72*/ 0.62**	0.32/ 0.2*/ 0.38**	0.26/ 0.29*/ 0.39**	0.32/ 0.4*/ 0.56**	0.5/ 0.37*/ 0.44**	0.25/ 0.24*/ 0.27**
Nitrate ions, mg/dm^3	40.0	5.57/ 5.5*/ 8**	7.05/ 8.2*/ 5.7**	3.22/ 2.3*/ 3.4**	2.75/ 4.5*/ 3.7**	1.52/ 3.7*/ 4.8**	2.82/ 4.6*/ 4.4**	2.07/ 1.9*/ 1.9**
Chemical oxygen demand, mg O_2/dm^3	15.0	20.75/ 26*/ 28.2**	18.5/ 29*/ 25.5**	12.4/ 26*/ 12.5**	11.4/ 19.5*/ 18**	12.4/ 17*/ 17.2**	16.7/ 22.2*/ 22**	8.17/ 9.25*/ 9.4**
Dissolved oxygen, mg O_2/dm^3	>6.0	8.65/ 9.4*/ 9.9**	10.55/ 9.2*/ 9.2**	10.5/ 9.8*/ 9.9**	9.6/ 9.4*/ 9.8**	10.4/ 9.9*/ 10.2**	9.5/ 9.6*/ 9.7**	10.45/ 10.2*/ 10**
Phosphate ions, mg/dm^3	0.17	0.14/ 0.121*/ 0.18**	0.13/ 0.13*/ 0.12**	0.13/ 0.14*/ 0.17**	0.088/ 0.11*/ 0.12**	0.14/ 0.22*/ 0.13**	0.21/ 0.14*/ 0.13**	0.056/ 0.07*/ 0.1**
Iron, mg/dm^3	0.1	0.46/ 0.44*/ 0.45**	0.37/ 0.34*/ 0.41**	0.13/ 0.29*/ 0.23**	0.14/ 0.26*/ 0.22**	0.11/ 0.23*/ 0.24**	0.17/ 0.21*/ 0.19**	0.065/ 0.1*/ 0.12**

* – data for 2017, ** – data for 2018

The data in Table 1 show the following exceedances of the MPC:

1. Biochemical oxygen demand (BOD): 2016 – at 1.45 times (observation post No. 1), 1.29 times (observation post No. 2), 1.02 times (observation post No. 5), 1.24 times (observation post No. 6); 2017 – 1.42 times (observation post No. 1), 1.42 times (observation post No. 2), 1.38 times (observation post No. 3), 1.24 times (observation post No. 4), 1.15 times (observation post No. 5), 1.47 times (observation post No. 6); 2018 – 1.47 times (observation post No. 1), 1.42 times (observation post No. 2), 1.11 times (observation post No. 3), 1.24 times (observation post No. 4), 1.24 times (observation post No. 5), 1.51 times (observation post No. 6).

BOD is an important ecological indicator of the state of natural reservoirs. With a high content of organic matter in the water, aerobic bacteria multiply rapidly, which require oxygen to survive. This can lead to a decrease in dissolved oxygen, create hypoxic conditions and the death of certain species of aquatic organisms. BOD does not include nitrification costs.

2. Suspended solids: 2016 – 24 times (observation post No. 1), 22.7 times (observation post No. 2), 17.6 times (observation post No. 3), 19.3 times (observation post No. 4), 12.3 times (observation post No. 5), 16.7 times (observation post No. 6), 9.3 times (observation post No. 7); 2017 – 24.6 times (observation post No. 1), 48.9 times (observation post No. 2), 23.3 (observation post No. 3), 20.27 times (observation post No. 4), 15.3 times (observation post No. 5), 19.3 times (observation post No. 6), 8.7 times (observation post No. 7); 2018 – 41.6 times (observation post No. 1), 22 times (observation post No. 2), 34 times (observation post No. 3), 22 times (observation post No. 4), 15.3 times (observation post No. 5), 19.6 times (No. 6), 10 times (observation post No. 7).

   Suspended substances enter the water due to the processes of erosion of soils and rocks, sedimentation of sediments, decomposition of aquatic organisms, chemical reactions, as well as inflows with domestic and industrial wastewater. Suspended substances affect the depth of penetration of sunlight, worsen the living conditions of aquatic organisms, lead to siltation of water bodies and cause their eutrophication.

3. Mineralization: 2017 – 1.04 times (observation post No. 1).
4. Sulphates: 2016 – 1.2 times (observation post No. 1), 1.2 times (observation post No. 2); 2017 – 1.5 times (observation post No. 1), 1.4 times (observation post No. 2); 2018 – 1.5 times (observation post No. 1), 1.9 times (No. 2).
5. Chlorides: 2017 – 1.3 times (observation post No. 1), 1.1 times (observation post No. 2); 2018 – 1.1 times (observation post No. 1), 1.1 times (observation post No. 2).
6. Ammonium: excess in all years in seven targets from 0.2 to 0.8 times, the largest excess of 0.4-0.8 times in observation posts No. 1-2.

   The increased content of sulfate ions, chloride ions and ammonium ions indicates that a significant amount of untreated and insufficiently treated wastewater from the private sector and agricultural production enters the river, which reduces the ability of natural water to self-purify.

7. Chemical oxygen demand: 2016 – 1.4 times (observation post No. 1), 1.2 times (observation post No. 2), 1.1 times (observation post No. 6); 2017 – 1.7 times (observation post No. 1), 1.9 times (observation post No. 2), 1.3 times (observation post No. 3), 1.3 times (observation post No. 4), 1.1 times (observation post No. 5), 1.5 times (observation post No. 6); 2018 – 1.9 times (observation post No. 1), 1.7 times (observation post No. 2), 1.2 times (observation post No. 4), 1.1 times (observation post No. 5), 1.5 times (observation post No. 6).

   Chemical oxygen demand (COD) is the amount of oxygen in milligrams or grams per 1 liter of water required for the oxidation of carbon-containing substances to CO_2, H_2O and NO_3, sulfur-containing – to sulfates and phosphorus-containing – to phosphates. COD is determined by oxidation of impurities of water using potassium dichromate ($K_2Cr_2O_7$) or sodium permanganate ($NaMnO_4$). The value of COD allows to estimate the content of oxidized substances, but does not provide information about their composition. Therefore, COD belongs to the generalized indicators.

8. Iron: excess in all years in seven observation posts from 0.06 to 0.46 times, the largest excess of 0.34-0.46 times in observation posts No. 1-2.
9. Soluble oxygen, nitrates, phosphates: no excesses were detected.

The most unprotected from the effects of brine are the Limnytsia River, Sivka River, Dniester River and groundwater, which are sources of drinking water. Exceedances of the maximum concentration limit of pollutants in these rivers were revealed, in particular, the largest exceedances are in the control area of the village. Voynyliv, Sivka River, the mouth of the Sivka River and on the control line of the village Sivka-Voynyliv, Dniester River.

Discussion of results

Due to insufficient funding for environmental and technological measures, their unsatisfactory scientific and technical coordination, lack of monitoring system in the predominant focus on eliminating the already manifested negative consequences, the level of safety in the Kalush mining region has a steady tendency to deteriorate and formation of a cross-border emergency. In order to eliminate the negative environmental consequences of mining activities and prevent emergencies within the Carpathian mining region, the following measures should be taken:

- eliminate and rehabilitate external dumps No. 1 and 4, settling ponds, tailings No. 1 and 2, sludge storage on the area of tailings No. 3;
- to liquidate the Piilo mine of the Dombrovsky quarry;
- to complete the brine filling of the Novo-Golyn mine;
- costs should be provided for the dry laying of the Golyn mine and the Khotyn mine field of the Kalush mine;
- anticipate the costs of liquidation of the trunks of the mines "Novo-Golin" and "Piilo";
- anticipate the costs of dismantling equipment, liquidation of buildings and structures of the Novo-Golin and Piilo mines of the Dombrovsky quarry, technological complex and surface remediation;
- create bases for monitoring observations;
- anticipate costs for monitoring studies;
- anticipate the costs of eliminating subsidence of the surface within the minefields;
- provide for the costs of measures to protect settlements from flooding and groundwater pollution;
- anticipate the costs of eliminating karst failures;
- anticipate the costs of maintaining the company during the waiting period and liquidation.

Taking into account the experience of international similar enterprises, underground mines should be eliminated by filling them with saturated brines, barrels filled with concrete bridges. Buildings and structures of the technological complex, as well as overhead buildings to be dismantled. Dispose of waste on external (or internal) dumps.

The most difficult is the liquidation of the Dombrovsky quarry, the southern part of which is filled with brine. Issues with brines formed in the quarry (as well as in tailings) are most difficult at the Potash Plant. Currently, there is no not only technology, but also a methodical approach to their use, disposal or disposal.

There is a possibility that involves the evaporation of brine, which will allow to obtain marketable products. At the same time, when choosing a method of liquidation of the quarry, the behavior of brines and fresh water in their contact is of great importance. A number of scientific studies are needed to confirm or disprove whether fresh water is mixed while in contact with brines or remains on their surface.

The method of liquidation of the Dombrovsky quarry influences the method of liquidation of dumps, tailings and accumulating tanks.

The following variants of liquidation of the Dombrovsky quarry of the State Enterprise "Potash Plant" are widespread among scientists: variant 1 – organization of a medical-recreational zone in the Dombrovsky quarry. The problem is that this water can and will be a source of salinization of the natural environment, as it will spread in the upper water layers to a depth of 18 m; option 2 – filling the remaining capacity of the quarry with fresh water with prior discharge of all brines of the State Enterprise "Potash Plant"; option 3 – filling the quarry with man-made waste SE "Potash Plant"; option 4 – Attracting investors to resume the development of Dombrowsky quarry.

Conclusions

From the above material, it can be concluded that the territory of the Dombrovsky quarry and adjacent rivers and timed underground aquifers is on the verge of ecological catastrophe. Without appropriate action, the state of the ecosystem in the area will deteriorate and lead to inevitable consequences that will have an impact for decades to come. The defined set of measures is necessary and urgent. It is important to draw the attention of all possible government and commercial organizations to this problem in order to work together to prevent and eliminate the problem.

The developed recommendations for reducing the negative impact of the Dombrovsky quarry and its components on the environment, in particular on water bodies – groundwater, Limnytsia River, Sivka River and Dniester River, with their proper and timely implementation will minimize the negative impact on the environment.

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Sustainable development – state and prospects (SDEV'2022)
Mirosław Borkowski, Oleksandr Moroz, Mykhailo Paslavskyi (red.)
Wydawnictwo GSW • Gdańsk 2023 • ISBN 978-83-66270-30-5

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Impact of biofuel production on the agricultural sector of the state

Abstract
The purpose of the study is to assess the impact of biofuel production by agrarian enterprises on their sustainable development. The main indicators of sustainable development of enterprises and the level of biofuel production are highlighted. The economic efficiency of production of different types of biofuel according to a sample of enterprises of the agrarian sector of the economy of Ukraine is estimated. The degree of the impact of biofuel production by Ukrainian agrarian enterprises on the indicators of their sustainable development has been established. For this purpose, both methods of deterministic analysis and statistical methods were used. The results of the application of these methods for a sample of Ukrainian agrarian enterprises showed that the impact of biofuel production on their sustainable development is quite significant. In particular, the dynamics of this production is positively correlated with the dynamics of operating income and profits of enterprises and with the change of most indicators that characterize the energy and environmental aspects of sustainable development of the surveyed companies. Among other things, there are statistically significant linear relationships between the growth rate of biofuel production and the growth rate of operating income and product profitability. Accordingly, there is a quadratic relationship between the growth rate of biofuel production and changes in the operating profit of the surveyed agrarian enterprises. Thus, the growth of biofuel production is one of the important drivers of the sustainable development of enterprises in the agrarian sector.

Introduction

The need to ensure the proper level of well-being of present and future generations in conditions of limited natural resources requires the sustainable development of countries and regions [1]. This problem should be primarily solved at the enterprise level as the activities of enterprises have a significant impact on the pace and proportions of socio-economic development of countries [2].

The complexity of the concept of sustainable development and a significant number of its goals should be taken into account [3]. In particular, at the national level, sustainable development should be interpreted as "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [4]. If we consider individual companies, their sustainable development can be equated with the long-term stable improvement of economic, social, environmental and other results of their activities [5].

Because sustainable development covers almost all aspects of the activities of governments, enterprises, households and individuals, the goals of this development are extremely diverse [6]. However, there are relationships between these goals, and in some cases, some contradictions. In particular, among the important goals of sustainable development are economic growth and an increase in the availability of clean energy. However, economic growth may lead to an increase in the need for energy resources, which will lead to an increase in the consumption of fossil fuels. To prevent this, there are two main ways of action. First, it is necessary to increase the level of efficiency in the use of non-renewable energy sources with the transition to the energy-saving economic development of enterprises, regions and countries as a whole [7]. Second, it is necessary to increase the share of green energy in national energy balances [8]. Under such conditions, a gradual reduction in the consumption of non-renewable energy sources will be ensured. This, in turn, will help to preserve their reserves for future generations [9], reduce production costs [10] and the energy dependence of countries [11] and improve the external [12].

In recent years, along with solar, wind and other types of green energy, the role of bioenergy has significantly increased in some countries around the world [13]. Particular attention is paid to the development of this type of alternative energy in the United States [14] and some countries of the European Union [15]. However, at present, bioenergy is also developing quite intensively in some Asian countries, in particular, in China [16]. The potential of bioenergy in Ukraine is also significant [17].

The growing influence of bioenergy in the modern world is due to the advantages that are inherent in it compared to traditional energy based on fossil energy sources[18]. In particular, these advantages include the possibility of making good use of significant amounts of waste of biological origin [19, 28-32]. The relative cheapness of certain types of biofuels should also be noted. In addition, biofuels can take a variety of forms, leading to a wide range of use of this fuel by both businesses and households [20]. Due to these reasons, the world has seen a growing demand for all main types of biofuel in recent years [21].

At the same time, various barriers often arise in the implementation of projects that increase energy efficiency and the transition to the use of alternative energy sources [22]. In particular, such barriers include insufficient financial resources available to enterprises and households [23], low level of economic efficiency of certain energy-saving projects [24], lack of competence in energy-saving issues [25], etc. A separate group of barriers to energy efficiency are information barriers [26]. The lack of information on the expected results of the implementation of energy projects may be one of the main reasons why businesses and households do not always agree to invest in such projects [27].

Concerning projects for the production of various types of biofuel, the main subjects in these projects are enterprises of the agrarian sector of the economy. At the same time, it is obvious that these companies, as potential investors, must have sufficiently complete and comprehensive information about the results of these projects. In particular, it is necessary to forecast the impact that biofuel production projects will have on the indicators of sustainable development of agrarian enterprises. The results of the retrospective analysis can be used for this purpose. These results are data obtained through the assessment of economic, social, environmental and other consequences of the implementation of biofuel production projects by those agrarian enterprises that have already implemented these projects. If these results are positive enough, it will encourage other agrarian enterprises to switch to the production of certain types of biofuel.

Given the above, the purpose of this study is to assess the influence of biofuel production by agrarian enterprises on their sustainable development. To achieve this goal, the following main tasks were solved: the main indicators of sustainable development of enterprises and the level of biofuel production were identified; the economic efficiency of production of different types of biofuels according to the sample of enterprises of the agrarian sector of the economy of Ukraine was estimated; the degree of influence of biofuel production by Ukrainian agrarian enterprises on the indicators of their sustainable development was established.

Research Methodology

Assessment of sustainable development of enterprises requires a preliminary selection of the indicators by which such an assessment can be performed. Thus, it seems expedient to carry out the division of these indicators into three such groups:

1) indicators that characterize the economic aspects of sustainable development of enterprises. These indicators include income and profit of enterprises, as well as relative indicators of economic efficiency, including product profitability;
2) indicators that characterize the social aspects of sustainable development of enterprises. These indicators include the number of staff and the average salary per employee;
3) indicators that characterize the energy and environmental aspects of sustainable development of enterprises. These indicators include the energy intensity of products, the share of reused waste, the share of clean energy in the structure of energy consumption, etc.

The assessment of the level of sustainable development of enterprises should, among other things, include measuring the dynamics of these indicators.

The issue of assessing the level of production of biofuel by a certain enterprise deserves special attention. Such an assessment can be based on the calculation of absolute and relative indicators. Absolute indicators can be the volume of biofuel production by the enterprise for a certain period of time in physical or cost units. Regarding the relative indicators of estimating the level of biofuel production by a certain enterprise, for their calculation, it is expedient to compare the absolute indicators with the total value of the enterprise's income from the manufacture and sale of all its products.

It should be noted that biofuel produced by agrarian enterprises can be divided into groups according to the way of use and sources of production.

In particular, by the way of use, we can distinguish biofuel produced by agrarian enterprises for resale and biofuel intended for internal consumption by these enterprises.

Regarding the division of biofuel by sources of production, it is necessary to distinguish between biofuel obtained from primary sources and biofuel obtained from secondary sources. If the secondary sources are mainly different types of waste, the production of biofuel from its primary sources often requires the creation of special "energy plantations". As a result, the sown area of traditional crop products (i.e. those used to meet food needs) may be reduced. Herefore, the use of microalgae and sewage sludge from sewage treatment plants as a raw material for biogas production is highly viable.

The division of biofuels described above in the context of this study is important because the production of different groups of biofuels can affect the pace and proportions of sustainable development of agrarian enterprises in different ways. As can be seen from Fig. 1, the increase in the production of biofuel by enterprises for their internal consumption does not directly affect sales volume. However, such an increase can positively affect the profitability of enterprises (if the cost of producing their own biofuel is less than the cost of purchasing equivalent amounts of traditional energy resources). In addition, from Fig. 1, it follows that the mechanism of impact of biofuel production on the indicators of sustainable development of agrarian enterprises is quite complex, which is reflected in the relevant relationships between these indicators. In particular, the growth of biofuel production may lead to an increase in the average wage of agrarian workers. This will happen if such growth causes both an increase in revenue and an increase in profits. Accordingly, under such conditions, the owners of the enterprise will be able to increase the payroll of employees without reducing the amount of profit due to them.

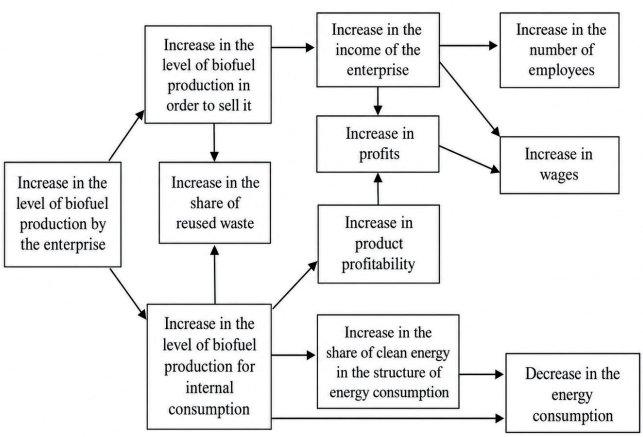


Fig. 1. The mechanism of influence of biofuel production on the indicators of sustainable development of agrarian enterprises

It can also be assumed that the growth of biofuel production from secondary sources will more positively affect the sustainable development of agrarian enterprises than the increase in biofuel production from its primary sources. This can be explained by the fact that the first option will increase the level of use of industrial waste and will not reduce the area under which traditional crop products will be grown. In general, assessing the impact of biofuel production on the sustainable development of agrarian enterprises requires the use of both methods of deterministic analysis and statistical methods. In particular, due to the deterministic analysis, it is possible to establish the share of the growth of certain indicators of sustainable development of enterprises due to their biofuel production. For this purpose, first, it is necessary to determine the change in the value of the relevant indicator in the reporting period compared to the base period due to the growth of biofuel production.

This change can be calculated using the following expressions:

1) for the value of operating profit of the enterprise:

$$\Delta P = \Delta R_b \cdot P_{ab} - \Delta R_t \cdot P_{at} + R_t \cdot \Delta P_{at}, \tag{1}$$

where ΔP is an increase in operating profit of the agrarian enterprise due to the growth of its biofuel production in the reporting period compared to the base period, monetary units; ΔR_b is an increase in income from the sale of biofuel produced by the enterprise, monetary units; P_{ab} is the profitability of production and sale of biofuel in the reporting period, unit share; ΔR_t is a decrease in income from the sale of traditional agrarian products by the enterprise due to increased production of biofuel, monetary units; Pat is the profitability of production and marketing of traditional agrarian products in the reporting period, unit share; R_t is an income from the sale of traditional agrarian products by the enterprise in the reporting period, monetary units; ΔP_{at} is an increase in profitability of production and sales of traditional agrarian products due to increased production of biofuel for own consumption (which, in turn, may reduce the specific costs of the enterprise for the purchase of energy), the share of the unit;

2) for the value of operating income of the enterprise:

$$\Delta R = \Delta R_b - \Delta R_t, \tag{2}$$

where ΔR is an increase in operating income of the agrarian enterprise due to the growth of its biofuel production in the reporting period compared to the base period, monetary units;

3) for the number of employees of the enterprise:

$$\Delta L = \frac{\Delta R_b}{V_b} - \frac{\Delta R_t}{V_t}, \tag{3}$$

where ΔL is an increase in the number of employees of the agrarian enterprise due to the growth of biofuel production in the reporting period compared to the base period, monetary units; V_b is the amount of income of the agrarian enterprise from the sale of biofuel per employee in the reporting period, monetary units per person; V_t is the amount of income of the agrarian enterprise from the sale of traditional agrarian products per employee in the reporting period, monetary units per person;

4) for the average salary per employee of the enterprise:

$$\Delta P_l = \frac{\Delta S_{pl}}{L}, \tag{4}$$

where ΔP_l is an increase in average wages per employee of an agrarian enterprise due to the growth of biofuel production in the reporting period compared to the base period, monetary units per person; ΔS_{pl} is an increase in the wage fund of the enterprise due to the growth of its biofuel production, monetary units; L is the number of employees of the agrarian enterprise in the reporting period, persons;

5) for the volumes of non-renewable energy sources used by the agrarian enterprise:

$$\Delta E = \Delta R_b \cdot e_b - \Delta R_t \cdot e_t - \Delta E_b, \tag{5}$$

where ΔP is an increase (decrease) in the volume of non-renewable energy sources used by the agrarian enterprise due to the growth of biofuel production in the reporting period compared to the base period, physical units of energy consumption; e_b is physical costs of non-renewable energy sources to obtain a monetary unit of income from the sale of biofuel produced by the enterprise in the reporting period, physical units of energy consumption per monetary unit; e_t is physical costs of non-renewable energy sources to obtain a monetary unit of income from the sale of traditional agricultural products by the enterprise in the reporting period, physical units of energy consumption per monetary unit; ΔE_b is the value of the decrease in consumption of non-renewable energy sources by the agrarian enterprise due to the increase in its biofuel production for domestic consumption in the reporting period compared to the base period, physical units.

Using the above expressions (1)-(5), we can assess the impact of the increase in biofuel production by agrarian enterprises on the relevant indicators of sustainable development. For this purpose, it is necessary to establish the share of the growth of the relevant indicator by increasing the volume of biofuel production in the total amount of this growth. It is also possible to assess the effectiveness of increasing the production of biofuels by a particular agrarian enterprise or a set of such enterprises. To do this, it is necessary to compare the values of indicators (1)-(5) with the amount of investment in biofuel production.

1) formation of a sample of agrarian enterprises that belong to a certain subsector of agriculture;
2) determination of the current level of biofuel production for each of the enterprises in the base and reporting periods;

3) assessment of the dynamics of the level of biofuel production by enterprises and the division of the whole set of enterprises into groups according to the value of the dynamics;
4) selection and calculation of the main indicators of sustainable development of the surveyed agrarian enterprises;
5) assessment of the statistical significance of the impact of biofuel production by the enterprise on sustainable development.

Also, to assess the impact of biofuel production on the sustainable development of agrarian enterprises, statistical relationships should be established between the indicators of the dynamics of the level of biofuel production and certain indicators of sustainable development. Then the presence of such an effect will be characterized by the appropriate degree of approximation of empirical data by regression equations and the statistical significance of the parameters of these equations.

Research results

To assess the impact of biofuel production on the sustainable development of agrarian enterprises, a sample of fifty such enterprises located in the western region of Ukraine was formed. The main activity of these enterprises is crop production. In particular, these enterprises grow corn, sunflower, soybeans, rapeseed and other types of crop products.

The survayed enterprises were divided into three groups depending on the level of dynamics of biofuel production in 2020 compared to 2016, namely:

1) enterprises with a low level of dynamics of biofuel production, in which the growth rate of such production for the study period did not exceed 10%. There were 17 such enterprises;
2) enterprises with an average level of dynamics of biofuel production, in which the growth rate of such production for the study period exceeded 10% but was less than 30%. There were 21 such enterprises;
3) enterprises with a high level of dynamics of biofuel production, in which the growth rate of such production for the study period was not less than 30%. There were 12 such enterprises.

The volumes of biofuel were measured in tons of conventional fuel.

For each of the groups of surveyed agrarian enterprises, the indicators of the impact of biofuel production on their sustainable development were determined and the efficiency of investing in such production was calculated (Table 1).

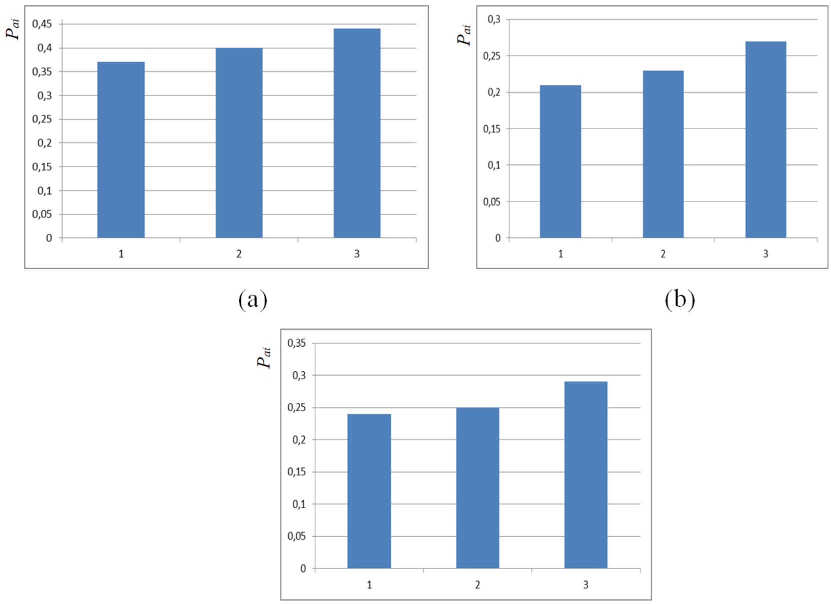
Table 1. Indicators of the impact of biofuel production on the sustainable development of agrarian enterprises and the results of evaluating the efficiency of investing in such production

Indicators	**Values of indicators averaged by groups of enterprises**		
	Enterprises with a low level of dynamics of biofuel production	**Enterprises with an average level of dynamics of biofuel production**	**Enterprises with a high level of dynamics of biofuel production**
1. The share of the growth of operating profit of enterprises due to the increase in biofuel production in the total growth of their operating profit, %	14.32	25.76	39.19
2. The share of the growth in operating income of enterprises due to the increase in biofuel production in the total growth in their operating income, %	12.48	23.43	37.62
3. The share of the growth of the number of employees of enterprises due to the increase in biofuel production in the total growth of the number of their employees, %	9.13	10.56	14.87
4. The share of the growth of the average salary of employees of enterprises due to the increase in biofuel production in the total growth of the average salary, %	6.02	7.48	9.70
5. The share of the decrease in the use of non-renewable energy sources due to the increase in biofuel production in the overall decrease in the use of these sources, %	15.87	22.98	40.75
6. Profitability of investments in the implementation of biofuel production projects, shares per unit	0.26	0.31	0.34
7. Increase in operating income per 1 USD of investments in the implementation of biofuel production projects, shares per unit	1.13	1.21	1.33
8. Decrease in the volumes of used non-renewable energy sources by 1 USD of investments in the implementation of biofuel production projects, kg of conventional fuel per 1 USD investment	0.07	0.12	0.19

As follows from the data presented in Table 1, for all indicators of assessing the impact of biofuel production on the sustainable development of agrarian enterprises, there is a significant increase in their value with increasing levels of dynamics of this production. Thus, according to these indicators, biofuel production has a significant impact on the sustainable development of the surveyed enterprises. Also, according to Table 1, the economic efficiency of biofuel production projects is on average higher at the enterprises with a higher growth rate of its production. This trend may be due to the effect of scale.

The level of economic efficiency of investing in biofuel production may depend on the structure of such production. Therefore, according to the surveyed enterprises, the return on investment in the production of certain types of biofuel was calculated.

As evidenced by the results of such calculations, which are shown in Fig. 2, the most profitable are investments in the production of solid biofuel. Also, for each type of biofuel, the return on investment increases with the increase in the level of dynamics of their production.



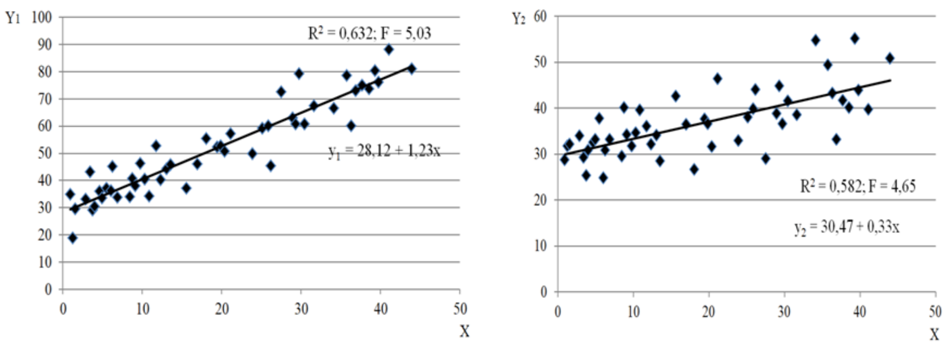
(c)

Fig. 2. Return on investment in production (P_{ai}): (a) pellets; (b) biodiesel; (c) bioethanol, where 1, 2 and 3 – enterprise groups according to low, medium and high levels of dynamics of biofuel production

It is expedient to pay special attention to the assessment of the influence of the level of dynamics of biofuel production by the surveyed agrarian enterprises on the change of the main indicators of their sustainable development. For this purpose, a method of analysis of variance can be used. According to the data presented in Table 2, for most indicators of sustainable development (except for employment and average wages), the actual value of the F-criterion exceeds its critical value with a significance level of $\alpha = 0.05$. Thus, we can state that the level of dynamics of biofuel production by agrarian enterprises affects the change of most indicators of their sustainable development. The same conclusion can be made for the indicators of the growth rate of incomes and profitability of production of the surveyed enterprises based on the results of the regression analysis (Fig. 3).

Table 2. Initial data and evaluation results of the impact of the dynamics of biofuel production by agrarian enterprises on the change of the main indicators of their sustainable development

Indicators	**Values of the growth rates of indicators, averaged by groups of enterprises, %**			**The value of the *F*-criterion**
	Enterprises with a low level of dynamics of biofuel production	**Enterprises with an average level of dynamics of biofuel production**	**Enterprises with a high level of dynamics of biofuel production**	
1. Operating income, USD	33.09	49.18	71.84	5.32
2. Operating profit, USD	35.43	63.61	88.22	5.78
3. Number of staff, persons	29.06	31.65	32.14	1.97
4. Average salary, USD/person	56.27	61.12	59.43	1.65
5. Energy consumption of products, kg of conventional fuel per 1 USD of income	16.58	27.36	38.29	4.51
6. Volumes of clean energy consumption, kg of conventional fuel	22.72	30.66	37.81	4.28
7. The share of reused waste, %	12.24	19.47	25.52	4.70
8. The share of clean energy in the structure of energy consumption, %	21.78	29.24	40.97	4.95



(a) (b)

Fig. 3. Graphs of regression relationships between the growth rate of biofuel production by the surveyed enterprises (x) and: (a) operating income (y_1); (b) product profitability (y_2)

As follows from the data shown in Fig. 3, for the surveyed enterprises, there are statistically significant linear relationships between the growth rate of biofuel production and the growth rate of operating income and product profitability. The profitability of products was defined as the ratio of operating profit to operating income. Since the operating profit of enterprises can be presented as the product of the value of income on product profitability, there is a quadratic relationship between the growth rate of biofuel production and changes in operating profit of the surveyed agrarian enterprises.

Conclusions

Assessing the impact of biofuel production on the sustainable development of agrarian enterprises requires a preliminary selection of indicators that characterize this development. These indicators should sufficiently characterize the economic, social, energy and environmental aspects of sustainable development. At the same time, assessing the impact of biofuel production on the sustainable development of agrarian enterprises requires the use of both methods of deterministic analysis and statistical methods. The results of the application of these methods for a sample of Ukrainian agrarian enterprises showed that the impact of biofuel production on their sustainable development is quite significant. In particular, the dynamics of this production is positively correlated with the dynamics of operating income and profits of enterprises and with the change of most indicators that characterize the energy and environmental aspects of sustainable development of the surveyed companies. Thus, the growth of biofuel production is one of the important drivers of sustainable development of enterprises in the agrarian sector.

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Sustainable development – state and prospects (SDEV'2022)
Mirosław Borkowski, Oleksandr Moroz, Mykhailo Paslavskyi (red.)
Wydawnictwo GSW • Gdańsk 2023 • ISBN 978-83-66270-30-5

UDC 504.064.36; 504.058; 628:47

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Information and analytical system of ecological water quality monitoring of mining and chemical enterprise at the stage of liquidation

Abstract
The analysis of surface and groundwater quality of State Enterprise "Rozdil Mining and Chemical Enterprise »Sirka«" is carried out. Based on the results of research on the contaminated area, the principles of environmental safety of the mining and chemical enterprise at the stage of liquidation have been developed. They are based on the principle of comprehensive environmental monitoring for the collection, storage and processing of data on pollution of various elements of the environment, which will provide forecasting of environmental changes in the territory of the mining and chemical enterprise. It is established that in order to ensure ecological balance in the zone of influence of State Enterprise "Rozdil Mining and Chemical Enterprise »Sirka«" it is necessary to conduct regular monitoring observations, maintenance, supervision and control over the condition of hydraulic structures, elimination of sources of pollution. The obtained research results indicate that there is a need to create an information-analytical monitoring system in order to effectively store, process and analyze data. Based on the obtained research results, a web application based on an interactive map of water sampling points and visualization of the obtained results of hydrochemical monitoring of Rozdil Lakes was created.

Introduction

The mining and chemical industry occupies one of the leading places in the infrastructure of our country's economy. But, at the same time, the activity of mining and chemical enterprises is a determining factor of technogenesis, which significantly complicates the ecological situation in local areas with changing landforms, hydrological and biogeochemical regimes of territories, caused by accumulation of significant industrial waste. As a result, there are various environmental problems associated with the pollution of various natural components of the environment, and thus the deterioration of the health of the local population.

One of the industrial basins that have undergone intensive exploitation is the Precarpathian sulfur-bearing basin. The main object within the sulfur-bearing basin was State Enterprise "Rozdil Mining and Chemical Enterprise »Sirka«", which was founded in 1953 in connection with the development of a fairly large Rozdil field. This enterprise developed rapidly in the 50s-80s of the twentieth century, when sulfur ore deposits were discovered, their geological exploration was carried out, three quarries (South, Central and North) were put into operation alternately. In the early 1990s, sulfur production ceased, and the process of restructuring the mining and chemical plant began. As of 2000, all explored resources have been extracted from the subsoil. Now there is a distorted natural landscape, man-made waste, contaminated soils and water bodies.

Analysis of the literature

Information about the state of the object of nature management is important in the process of making effective decisions. Usually, in practice, decisions on the management of nature objects are made in conditions of insufficient information about the object of management [1, 2]. This is due to the exceptional complexity of natural systems, their individual uniqueness and the inevitability of natural chain reactions, the direction of which is often difficult to predict [3, 4]. To effectively solve the scientific and practical problem associated with the process of managing the state of the object of nature, it is necessary to develop effective and adequate mathematical models that would sufficiently describe the causal nature of the processes occurring in the objects of nature under the influence natural and anthropogenic factors [5].

Assessment and forecasting of the state of environmental components is carried out based on data obtained from regular observations – environmental monitoring. The use of environmental monitoring will allow [6]:

- obtain information based on experimental research in special laboratories;
- to study the actual state of the environment or its components based on the results of observations;
- model the development of the environment or its components using a computer;
- use the above information as a basis for forecasting possible changes in the state of the environment or its components.

Ukraine has an extensive system of environmental monitoring. However, in the current systems of environmental monitoring in Ukraine, the process of collecting and processing information is mostly not automated but based on laboratory and chemical methods of sample analysis and is used mostly for statistical analysis, much less – for operational management decisions [6, 7]. A unified methodology for collecting, processing, accumulating and transmitting monitoring information has not been developed, and the functioning of individual departmental monitoring systems has not been coordinated [8]. This organization of the monitoring system leads to significant time and money, which reduces the efficiency of the monitoring system itself. Today, there are several computerized and automated systems, including intelligent ones, that are able to provide support for management decisions in the process of managing the state of the components of the environment [8, 9].

Today, an important scientific task is not only to create management systems for the state of the components of the environment, but also to ensure the intellectualization of management support functions for more accurate, fast and reliable implementation [6, 10]. Adaptive automated management system of the ecological situation in the contaminated area, in which the intellectualization of decision support is implemented, should have such functions as [6, 8]:

1) conducting intellectual monitoring;
2) automated data collection, processing, and storage;
3) automated formation of alternative management scenarios;
4) development and implementation of rational control influences;
5) exchange of information subsystems with each other and with the external environment.

The tasks of such systems are to control the main indicators of nature objects, their processing using artificial intelligence methods to develop management decisions aimed at reducing the content of environmental pollution, as well as to prevent catastrophic situations [11, 12].

Topicality

The ecological situation within State Enterprise "Rozdil Mining and Chemical Enterprise »Sirka«" is one of the tensest in Ukraine. Half a century of history of sulfur deposit development, production of mineral fertilizers, as well as difficult financial and economic condition of the enterprise in the last 20 years, was accompanied by various negative environmental consequences: creation of deep quarries, pollution of soils, groundwater and surface water with acid effluents, atmospheric air with hydrogen sulfide. Many of all solid industrial wastes of Lviv region are accumulated here.

Researchers at Lviv Polytechnic National University are conducting research aimed at improving the methodology for assessing indicators that determine the level of environmental hazard after the closure of a mining and chemical enterprise based on the analysis of environmental impacts of major sources of danger.

There are 11 sources of danger on the territory of State Enterprise "Rozdil Mining and Chemical Enterprise »Sirka«":

- phosphogypsum;
- lump sulfur;
- flotation tails;
- flooded quarries;
- sediments of circulating waters;
- modifier type "MG", made of neutralized tar residues and boiler residues of maleic anhydride;
- landfill;
- surface waters;
- groundwater;
- contaminated soils;
- exogenous geological processes and relief distortion.

Monitoring the condition and quality of surface and groundwater of a mining and chemical enterprise at the liquidation stage is no less important. The lack of adequate funding for hydrogeological work has led to the complete decline of groundwater monitoring not only of mining and chemical companies over the last decade. At the same time, in European countries, the issues of resource assessment and groundwater monitoring are a priority in the activities of geological services. Therefore, urgent measures need to be taken to resume monitoring and reform its European-style system.

Research results

The results of hydrochemical monitoring of Rozdil Lakes show that in the surface layer of waters of all Rozdil lakes and at the source of Lake Hlyboke exceeded the normative indicators for mineralization and sulfates, on Lake Serednie – and for phosphates. According to the results of chemical analysis of water flowing through the canal from Lake Hlyboke to the Dniester River, it was found that the level of water mineralization exceeded the MPC by 2.4 times, sulfates – 3 times. At the same time, the monitoring of Strontium and Fluorine content provided by the observation program in previous years was stopped. An urgent task for the company today is to solve the problems of use of lakes and culverts, sources of funding for their maintenance, supervision and control. Assessment of water quality indicators makes it possible to establish compliance or non-compliance of water of a certain water body with the requirements set by certain water users.

In the surface layer of waters of all Rozdil lakes the exceeding of normative indicators on mineralization (MPC – 1000 mg/dm^3) and sulphates (MPC – 100 mg/dm^3) is fixed. In lakes Kysle and Seredne, the permissible values for phosphates were also exceeded (MPC – 0 mg/dm^3). In Lake Seredne the pH is 5.25 at a rate of 6.5 to 8.5. In the channel of Lake Hlyboke-Dniester the maximum concentration limit was exceeded according to the following indicators: pH is 6.05 (norm – from 6.5 to 8.5), sulfates – 1665.3 mg/dm^3 (MPC – 100 mg/dm^3), ammonium nitrogen – 4.6 mg/dm^3 (MPC – 0.5 mg/dm^3), mineralization – 2498.6 mg/dm^3 (MPC – 1000 mg/dm^3).

Discussion of results

To ensure ecological balance in the area of influence of State Enterprise "Rozdil Mining and Chemical Enterprise »Sirka«" it is necessary:

- conducting regular monitoring observations;
- identification of stable sources of funding for maintenance, supervision and control over the condition of hydraulic structures;
- elimination of existing sources of pollution – tar composition, landfill of the city, lump of sulfur, phosphogypsum dump;
- reclamation of disturbed lands of the dry mineral fertilizers plant.

Based on the results of research on the contaminated area, the principles of environmental safety of the mining and chemical enterprise at the liquidation stage were developed, based on the principle of integrated environmental monitoring, which will provide forecasting of environmental changes in the contaminated area.

State Enterprise "Rozdil Mining and Chemical Enterprise »Sirka«" is in the process of liquidation, but still poses a threat to the environment. Therefore, there is a need to create an information-analytical monitoring system (IASM). IASM is a computer system that can be used to obtain, create information and process and analyze it. Elaboration and analysis are not the only advantages of the information-analytical system. It can also provide forecasting – determining the consequences of the situation. The forecasting function predicts possible changes in the environment on the basis of data on the current ecological state of the enterprise.

The purpose of such a system is the efficient storage, processing and analysis of data. Depending on the type of impact, the organization of the monitoring system at mining facilities should be considered according to the sources of environmental impact, as each source can have several types of impact on the elements of the biosphere. The creation of such a system is an important step towards improving the environmental safety of the territory, because timely information on the environmental status ensures timely elimination of the problem with minimal risks and consequences [8]. Important in the information-analytical subsystem of industrial waste is the creation of information base – information on the generation, availability, removal and use of industrial waste, location of man-made objects, such as mine workings, areas of industrial waste and change their quantity and size over time. Information on the composition and hazards of waste to the environment is also important [6]. The result of the research is a map with the selection of zones of man-made impact of each source. This information is part of the IASM on the territory of the complex for the period of completion.

Ecological monitoring of water bodies on the territory of the enterprise similar to the system of ecological soil monitoring should be based on the following data: sampling, data collection, analysis of the existing set of environmental measures to reduce water pollution, identify sources of water pollution, environmental assessment water bodies, forecasting the process of pollution of water bodies and violation of ecological balance, creation of information-analytical or geo-information system of observation and monitoring, development of measures to improve the ecological condition and restore ecological balance.

General scheme of IASM of the mining and chemical enterprise [8]:

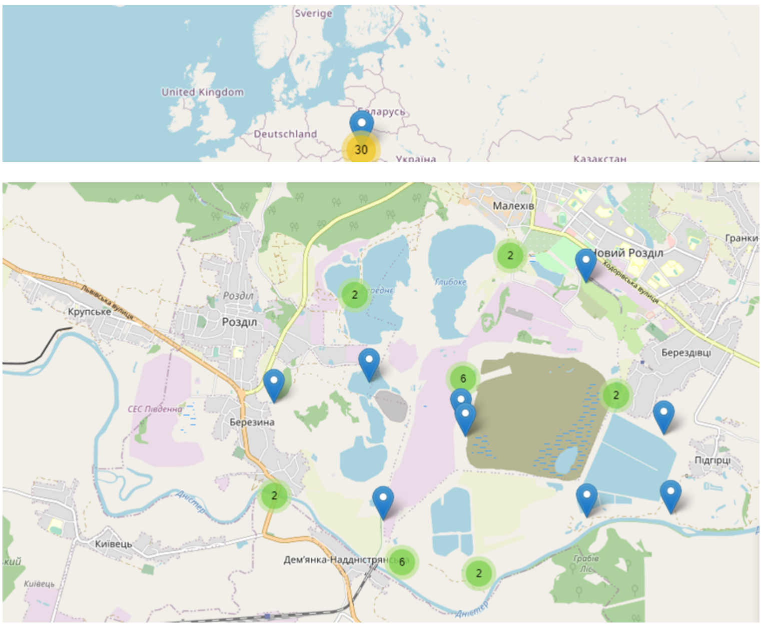
1) collection of experimental data;
2) laboratory tests of selected samples;
3) computer data processing;
4) comparison of the obtained results with normative indicators;
5) database of results of analyses of samples and research of the territory;
6) superimposition of element-by-element digital research results on the map;
7) map of total indicators of the result of the study of environmental elements;
8) ecological map of the study area;
9) forecasting changes in chemical, biological, physical pollution of the environment of the study area;
10) measures to improve the environmental safety of the study area.

Acceleration and improvement of the work of employees of research ecological stations, as well as visualization of the ecological state of the area in the form of interactive maps of pollution can significantly improve the state of environmental monitoring of the region. Analogues of the information system of accumulation and visualization of environmental measurements are any software that has the ability to visualize statistics.

Visual information is better perceived and allows you to convey quickly and effectively to the viewer their own thoughts and ideas. Physiologically, the perception of visual information is fundamental to man. In addition to excellent processing by our brain, data visualization has several advantages:

1. Focusing on different aspects of the data.
2. Analysis of a large data set with a complex structure.
3. Reduction of information overload of the person and retention of his attention.
4. Unambiguity and clarity of the output data.
5. Highlighting the relationships and relationships contained in the information.

Based on the obtained research results, a web application was created on the basis of an interactive map of water sampling points and visualization of the obtained results of hydrochemical monitoring of Rozdil Lakes. This web application is available on the Internet at the link: http://ecotest.infostore.in.ua/. The display of the interactive monitoring map is configured with the help of interactive maps Leaflet – an open-source JavaScript library for displaying maps on html-pages. The library implements support for layers of maps that are built on technology: WMS, GeoJSON, or vector surface mapping. Web map applications can be great tools for making various geological datasets accessible and visualized with easy web browser access, interactive visualization, and ease of use.



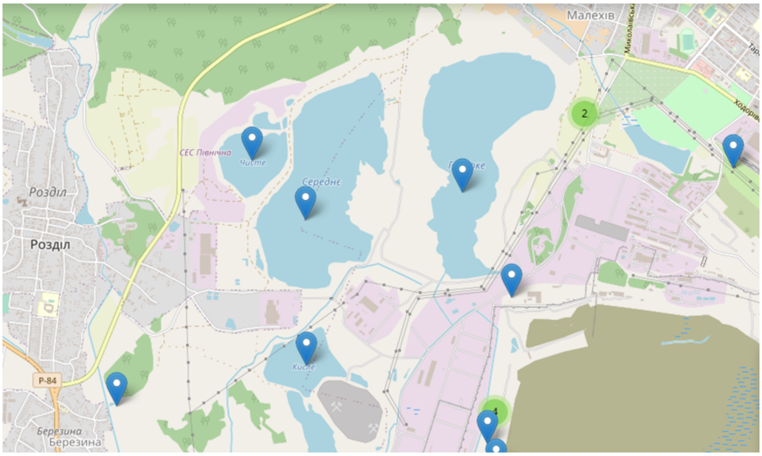


Fig. 1. Screens of the web application of the interactive map of water sampling on the territory of State Enterprise “Rozdil Mining and Chemical Enterprise »Sirka«”

Chart.js is used to build the display of graphic information – a popular tool designed to create graphs and charts. This library allows you to create graphs and charts of any type, as well as build data on a time range and logarithmic scale. It also has built-in animation tools that will allow you to effectively modify graphics depending on new data, as well as experiment with colour.

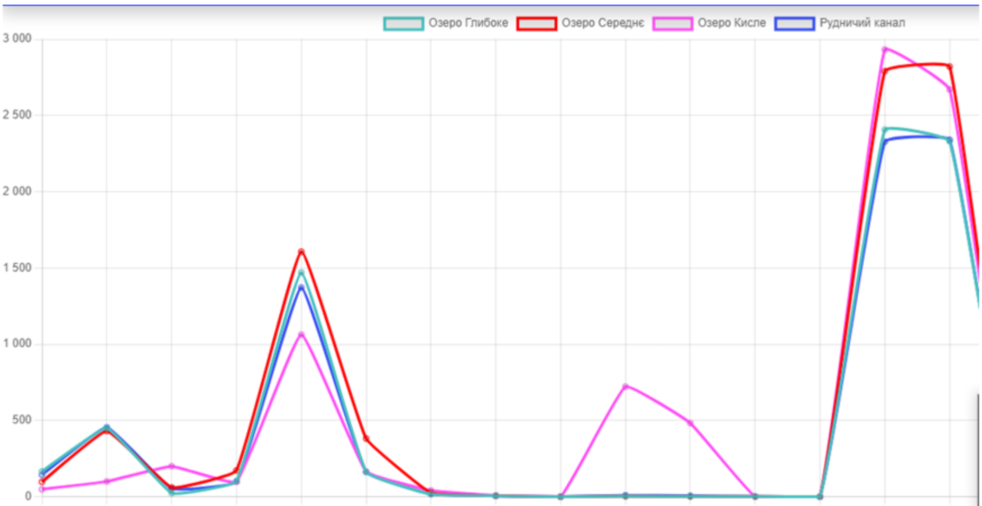


Fig. 2 Screen of the web application for visualization of the results of the analysis of water samples on the territory of State Enterprise “Rozdil Mining and Chemical Enterprise »Sirka«”

Conclusions

1. The quality of surface and groundwater of the mining and chemical enterprise at the stage of liquidation has been studied. It is established that to ensure ecological balance in the area of influence of State Enterprise "Rozdil Mining and Chemical Enterprise »Sirka«" it is necessary:
   - conducting regular monitoring observations;
   - maintenance, supervision, and control over the condition of hydraulic structures;
   - elimination of sources of pollution;
   - reclamation of disturbed lands on the territory of the mineral fertilizer plant.
2. Based on the results of research on the contaminated area, the principles of environmental safety of the mining and chemical enterprise at the liquidation stage were developed, based on the principle of integrated environmental monitoring based on.
3. To reduce the threat to the environment from mining and chemical enterprises at the liquidation stage, it is important to create an information and analytical system for the effective storage, processing, and analysis of monitoring data.
4. Based on the obtained research results, a web application based on an interactive map of water sampling points and visualization of the obtained results of hydrochemical monitoring of Rozdil Lakes was created.

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Sustainable development – state and prospects (SDEV'2022)
Mirosław Borkowski, Oleksandr Moroz, Mykhailo Paslavskyi (red.)
Wydawnictwo GSW • Gdańsk 2023 • ISBN 978-83-66270-30-5

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Qualitative assessment of cultural ecosystem services of the spatio-temporal geosystem for the development of recreation and tourism using fuzzy logic and QFD

Abstract

The paper proposes a comprehensive method of qualitative evaluation of services provided by various providers, which are usually expressed by characteristics that do not have a quantitative representation. The research foresees the application of the well-known method of deployment of quality functions (Quality Function Deployment), the development of which consists in the possibility of determining the coefficients of weighting of technical characteristics of cultural ecosystem services for recreation and tourism of the spatiotemporal geosystem. To take into account the priority of consumer requirements, the expert method of pairwise comparisons was applied, which was modified so that all possible conclusions could be taken into account, in particular, the evaluation of the equivalence of characteristics was applied. In order to obtain the degree of correlation between the characteristics determined by experts based on consumer requirements and the technical characteristics of cultural ecosystem services for recreation and tourism, it is proposed to use the fuzzy logic method. Since both the presence of correlations links and the degree of correlation between consumer requirements and technical characteristics are the result of the interaction of a set of various factors, among which a significant number may be random, based on the central limit theorem, as well as the experience of applying correlation coefficients in other areas, a conclusion is drawn, that the probability distribution function of correlation degrees is well described by a Gaussian curve. The value of the technical characteristics of the specified ecosystem services for three spatio-temporal geosystems was also obtained using the fuzzy logic method. Since the technical characteristics of services formed by spatio-temporal geosystems are mainly expressed by qualitative indicators, nothing is known about the nature of changes in their values, and there is a need to combine disparate characteristics, so it is proposed to use the triangular membership function.

Introduction

Ecosystem services (ES) are the useful resources and benefits that humans can obtain from nature. The satisfaction of fundamental human needs in the environment and food products depends on the EP, and therefore the level of our life directly depends on them. Scientists and politicians of most countries of the world recognize this interpretation. In the UN document "Millennium Ecosystem Assessment", ecosystem services are unequivocally called "the direct and indirect contribution of ecosystems to human well-being" [1].

Ecosystem services can be defined as "a set of ecosystem functions that are beneficial to humans" [2]. They are the result of auxiliary processes operating at different time and space scales [3].These general definitions are widely accepted, but the classification of services and their application to decision-making is accompanied by a number of uncertainties. In particular, there are different semantic interpretations of the term "ecosystem services", depending on the specific purpose [4]. According to R. Costanza and Folke, ES "represents the receipt of human benefits from ecosystem functions (EF), directly or indirectly" [5]. According to the definition of G. Daily [6, 7] ES, for which he uses the term "services of nature", these are "conditions and processes", as well as "life-supporting functions". In the definition of the UN document "Millennium Ecosystem Assessment" [1], which was widely used in international scientific studies, they emphasize the direct connection between ES and the benefits that are created directly or indirectly by ecological systems for humans. Based on the MEA approach, within the framework of the international project "Economics of Ecosystems and Biodiversity", ES is defined as the direct and indirect contribution of ecosystems to human well-being [8].

J. Boyd & S. Banzhaf [9] use a different interpretation of the term. According to their definition, ES is an ecological component or structure that is directly consumed or used to create human well-being. Therefore, indirect processes and functions are not considered ES, but intermediate ecological components. In contrast to the above definition, Fisher and co-authors [4] suggest that EP is "certain active or passive use of ecosystems to create human well-being" [4]. Therefore, services cover the organization and structure of ecosystems, as well as processes and/or functions, if they are directly or indirectly consumed by humans.

There are two main reasons why the concept of "ecosystem services" and the related concept of "natural capital" have shown their feasibility in territory management and decision-making. First, they help synthesize other essential ecological and economic concepts, enabling researchers and managers to integrate social and ecological systems. Second, scientists and politicians can use these concepts to evaluate the economic and political trade-offs between territorial development and biodiversity conservation.

There are three types of EP evaluations, namely: ecological, which is based on indicators of the state of ecosystems; monetary, which can be easily integrated into decision-making mechanisms, and social, aimed at society's perception of EP as a means to avoid possible conflicts and ensure agreed decisions [10].

Literature Data Analysis and Purpose of the Studies

An analysis of recent advances in the field of ecosystem services studies by a group of experts [11] based on a quantitative synthesis of 153 publications during 1997-2021 showed that 50% of all studies were performed in only 6 countries (mainly the USA and China), while the value of all of ecosystem services in these countries constitutes only 23.5% of their total value on a global scale. Less than 40% of the studies used primary observational data, and almost 2/3 of the studies were based on secondary results. The simulation modeling method was rarely used. And in general, less than 1/3 of the works have raw data for mapping ecosystem services. More than 50% of studies consider ecosystem services in isolation, without taking into account interrelationships and feedbacks and are fragmentary. The authors identified the following main areas of EP study: obtaining informational data about the environment based on modeling the functioning of ecosystems with feedback, checking the correctness and reliability of the obtained models; comparison of advantages and disadvantages during changes in the types of human and economic activity; consequences for ecosystems located outside the territory – the so-called "external effect"; stakeholder engagement.

Modern social relations are often called a consumer society, which is characterized by the value assessment of any material goods. Therefore, the desire to give a value estimate of the ES is obvious. A comprehensive cost assessment of ESs is too difficult due to their diversity. Therefore, it is appropriate to present ES as a set of subsets of ecological processes and structures. Such analytical work was carried out in the study [12], where 23 functions and related ecological processes and structures were considered and described in detail.

At the same time, taking into account the concept of sustainable development, authorities need to clearly define and adhere to priorities regarding the consequences of various management decisions in the economic, social and environmental spheres. In particular, the strategic tasks of Ukraine's development should be aimed at the careful and rational use of natural capital.This requires both an objective assessment of the natural resource potential and the use of assessment results for alternative options for economic use [13]. When developing strategic programs for territorial and sectoral development of the economy, it is important to take into account the efficiency of the use of resources on a global scale. And this requires the use of modern complex approaches to the assessment of resource potential, in particular ES, which determines the relevance of this study.

The nature of human interaction with the environment is determined by the flow of substances, energies and information. By changing the value of any flow of mass, energy, information, human actions from the minimally significant to the maximally possible, it is possible to go through a number of characteristic states of interaction in the "human – environment of functioning" system. According to the ecosystem approach based on the multicompartmental concept [14], natural renewable and non-renewable resources should be considered, on the one hand, as the main components of natural capital, on the other – as compartments of the spatio-temporal geosystem (STG), taking into account the functions they perform functions and services. That is, EP are the benefits that a person receives from the operation of the STG, and they should be interpreted as material, energy and information flows generated by natural capital reserves in combination with physical (buildings, equipment) and human capital and ensure the well-being of mankind [15].

The mechanism of obtaining ES of a STG consists in the interaction of its compartments, tiers and subsystems with the atmosphere, water, soil, etc. and in maintaining their qualitative and quantitative parameters at the optimal ecological level for obtaining benefits by consumers. In particular, the recreational and tourist services of the STG include recreation in nature, health of the body, observation of nature, satisfaction of cultural and cognitive needs, hunting, mushroom and berry picking, and others. In this case, recreation is not of a commercial nature, but is aimed at meeting the needs of the population for recreation and health improvement [16, 17].

The analysis of the ISO 9001:2015 and ISO 14001:2015 standards shows that their requirements for standardizing the quality of STG include, in particular, a thorough study of not only the external and internal environment of STG, a thorough study of not only the external and internal environment of STG, but also the application of a process approach to assessing the impact of the main resources of the external environment on the basic processes of ecosystem functioning, such as, for example, photosynthesis and respiration, as well as the development of new methods for assessing the state at which STGs are able to maintain their integrity and provide ecosystem services under constant influence from technical systems.

The mutual influence of different services or changes in the STG itself can have different effects on their provision of their own ES. This makes STGs very difficult for qualitative evaluation.

Methods of the Study

The task of the research was to present a method for obtaining an assessment of cultural ecosystem services for recreation and tourism (hereinafter – cultural ES) of STG. The basis of the method is the establishment of connections between the requirements of consumers, which they place on cultural ES STG, and its technical characteristics. The obtained correlations were used for the qualitative assessment of cultural ES of three different STGs.

It is proposed to use expert evaluation, in particular the methods of pairwise comparisons and direct evaluation, in combination with the method of *Quality Function Deployment* (QFD) and *Fuzzy Logic* on the example of the evaluation of cultural ES STG of the Carpathian mountain forests. The input data is obtained by surveying a group of experts selected on the basis of their knowledge and experience in the relevant field.

Since the input variables in the traditional application of the QFD method are mostly represented by clear numerical values and as a result of their processing also receive accurate estimates, and the implementation of the QFD method in this study requires a combination of various input data presented in the form of fuzzy linguistic variables, which are rather imprecise and subjective, it is proposed to use the technique of transforming fuzzy data into clear data. At the same time, it is known that human wishes, opinions, assessments of importance, the essentiality of connections between various requirements (for example, between consumer requirements and technical characteristics) are mostly expressed in the form of statements, which are also characterized by uncertainty.

The task was to overcome this vagueness, uncertainty and, in general, inaccuracy of human statements. To solve these problems, it is proposed to use defuzzification of the collected fuzzy data.

The QFD method [18] consists in building so-called "Houses of Quality" (HoQ). HoQ is a formalized representation of the values of various input values, suitable for their processing according to a certain algorithm. The appearance of such a "house of quality" on the example of the tasks set in the work is shown in Table 1.

Table 1. Sample HoQ for determining the weighting of quality indicators of cultural ES STGs

The set of characteristics according to the requirements of the consumer {RCX_i}	**The priority of each consumer requirement – *Im***	**The set of technical characteristics {TC_j} and their corresponding quantitative values q_j**					
		TC_1	**TC_2**	**....**	**TC_j**	**....**	**TC_m**
		q_1	**q_2**	**....**	**q_j**	**....**	**q_m**
RCX_1	Im_1	r_{11}	r_{12}	....	r_{1j}	....	r_{1m}
RCX_2	Im_2	r_{21}	r_{22}	....	r_{2j}	....	r_{2m}
....	....	....	....	....	....	....	....
RCX_i	Im_i	r_{i1}	r_{i2}	....	r_{ij}	....	r_{im}
....	....	....	....	....	....	....	....
RCX_n	Im_n	r_{n1}	r_{n2}	....	r_{nj}	....	r_{nm}
		Weight of each technical characteristic – w_j					
		w_1	w_2	....	w_j	....	w_m

The result of executing the algorithm according to Table 1 is a complete set of comparative estimates $\{w_j\}$, which in our case are weighting coefficients of technical characteristics and can be used directly or as input data for the next house. The first QFD table is usually called the first phase or planning matrix.

The method implementation process for each QFD table contains several typical steps. During the construction of the planning matrix, the first step is to identify the customer's requirements. At this stage, the needs of the consumer are determined through the expression of their expectations and priorities, which we will call consumer requirements. For the most part, these are the expected benefits of an object, product, or service, expressed in the consumer's own words.

Next, they try to specify the consumer's requirements in the form of an ordered collection and present them with characteristics that take into account the consumer's perception – characteristics according to consumer requirements (CRC). It depends on the experience of the expert team members. The table is filled with data obtained from questionnaires, interviews or surveys of target groups. The field of characteristics according to the requirements of the consumer of CRC_i (Table 1) is represented by values that do not need to be described by quantitative values, but only by verbal formulations. Since the ultimate goal here is to determine the priority Imi of each

CR_i or CRC_i, it is advisable to apply the appropriate expert evaluation, for example, the method of pairwise comparisons.

The next step is the process of determining the technical requirements for the service. Often they are called measurable because technical characteristics require that they can be determined objectively. Such characteristics are called technical, and in table NoQ (Table 1) they are represented by the area $\{TC_j\}$. For the evaluation of cultural ESs, part of TC can be represented by physical or other measurable values, and the part, as practice shows, is significantly larger – these values are expressed by linguistic variables. It is obvious that to represent them with quantitative values, it is advisable to apply fuzzy logic.

The TC nomenclature is determined by a multidisciplinary team of experts who are perfectly oriented both in the specifics of the object, product or service, and in the methods of TC regulation and determination.

Further filling of the NoQ table consists in obtaining correlations between the characteristics of the CR and TC – the r_{nm} field (Table 1). Experts also determine the mutual influence of technical characteristics and characteristics according to consumer requirements. Here, it is important not only the presence, but also the degree of mutual influence of TC and CR, for the establishment of which fuzzy logic will also be well provided.

Next, determine the weights of TC, determined by the range of w_j values, located at the base of the quality house (Table 1). Weights are one of the main outputs of HoQ and are defined as:

$$w_j = \sum_{i=1}^{n} \mathrm{Im}_i \cdot r_{ij} \tag{1}$$

where r_{ij} is the value of the correlation coefficient of $\mathrm{TC_j}$ with $\mathrm{CR_i}$, I_{mi} is the priority of $\mathrm{CR_i}$.

In order to combine the opinion of all individual decisions of experts, a common presentation of data is necessary. At the same time, experts express their conclusions in words and phrases – fuzzy linguistic variables that make it possible to present various aspects of human interpretation (utterance). Also, experts combine fuzzy linguistic variables with numerous linguistic criteria, such as low, medium, high – linguistic terms. At the same time, fuzzyfication is used – the transition from a clear value of some parameter to a fuzzy value of some linguistic variable. To carry out such a transition, the function of belongingness of the values of the linguistic variable to the fuzzy set A is necessary. The process of fuzzification consists in the early collection of expert information and its processing to build the functions of belonging of the input values [19]. The purpose of fuzzification is to establish correspondence between the specific (usually numerical) value of a separate input variable of the system of fuzzy logical inference and the value of the membership function of the corresponding term of the input linguistic variable. As a result of fuzzification, specific values of the membership functions for each linguistic term of the system of fuzzy logical inference are established for all input variables.

By the fuzzy set A we will understand the set of ordered pairs consisting of elements x of the universal set X and their corresponding degrees of belonging $\mu_A(x)$: $A = \{(x, \mu_A(x)) \mid x \;\; X\}$. $\mu_A(x)$ is a membership function (characteristic function), indicating how much (to what degree) the element x belongs to the fuzzy set A [20]. The function $\mu_A(x)$ takes individual values among a certain linearly ordered set M. The set M is called the set of degrees of belonging. Often the segment [0, 1] is chosen as M. If M contains only two elements, i.e. $M = \{0, 1\}$, then the fuzzy set is interpreted as a clear set. In our case, let A be a class of objects with an uncountable set of degrees of belonging and be normal, i.e. its height:

$$\sup_{x \in X} \mu_A(x) = 1.$$

Then a certain membership function can be used for A triangular, trapezoidal, S- and Z-shaped, sigmoidal, U-shaped, in particular Gaussian, and singleton functions are most often used [21].

Next, defuzzification is performed – the procedure of transforming the values of the fuzzy set A into clear values according to the degree of belonging. In the theory of fuzzy sets, the defuzzification procedure is analogous to finding the location characteristics – mathematical expectation, mode, median – of random variables in the theory of probabilities [22].

In our case, defuzzification is the process of obtaining an estimate of a fuzzy number, which is characterized by its shape, scale, height, and relative location on the x-axis. The transformation of fuzzy data into clear data is carried out through fuzzy composition procedures. By determining the left and right values, the maximum and minimum of fuzzy numbers are obtained. According to membership functions of fuzzy numbers, the overall value is defined as a weighted average.

In the case of correlations between the characteristics according to CR and TC for the "house of quality" (Table 1), their values are obtained from the formula:

$$\bar{r} = \sum_{k=1}^{l} r_k \mu(r_k) \Big/ \sum_{k=1}^{l} \mu(r_k)$$

which will characterize decision-making based on the conclusions of $k = 1, 2, \ldots, l$ experts according to the vague estimates of each k-th expert about the degree of influence of criterion j – technical characteristics on criterion i – consumer demand.

It is expedient to present the result of the implementation of the method on the example of obtaining qualitative evaluations of several providers of cultural ES STG for their comparative characteristics [23]. We will look for a qualitative assessment using the universal formula:

$$U = F(w_1 q_1, w_2 q_2, \ldots, w_j q_j, \ldots, w_{m-1} q_{m-1}, w_m q_m), \tag{2}$$

where F is a functional that combines a set of q_j – TC values, taking into account their weights w_j.

For example, in the case of arithmetic summation, formula (2) will look like this:

$$U = \frac{\sum_{j=1}^{m} w_j \cdot q_j}{\sum_{j=1}^{m} w_j}. \tag{3}$$

Experts with experience in the relevant field should be selected to collect data and obtain initial estimates. Managers, quality engineers and representatives of service users can be experts.

Results of the Studies

Determining consumers' requirements consists in forming by experts a list of quality characteristics established based on the results of a survey of representatives of users of cultural EPs STG, and establishing degrees of their significance – priority for the consumer. According to experts' assessments, a list of nine characteristics was determined that most fully reflect the consumer's requirements for the quality properties of cultural ESs (Table 2).

Table 2. Demands of consumers and CRC to cultural ES of the Carpathian mountain forests

No.	Consumer requirements	The name of the CRC	Designation
1	A comfortable climate	The physical and geographical characteristics of the territory are close to comfortable ones	RES(1)
2	Access to interesting objects	The level of accessibility to the natural and historical and cultural potential of the territory	RES(2)
3	A favorable geographic location	The level of costs for access to the service	RES(3)
4	Absence of dirt and garbage	The degree of pollution of environmental components	RES(4)
5	Beautiful and diverse landscapes	The degree of attractiveness of landscapes	RES(5)
6	Attractiveness of cultural objects	The level of aesthetic properties of objects	RES(6)
7	The uniqueness of cultural objects	The presence of objects of world significance entered into the protection lists	RES(7)
8	Safe location	The level of recreational development of the territory	RES(8)
9	Conditions for active tourism	The degree of provision of faunal and floristic resources	RES(9)

In the work, it is proposed to determine the priority – Im_i CR using the expert method of pairwise comparisons [24]. The method of pairwise comparisons is a matrix method based on a pairwise comparison of all n characteristics to determine the most important one in each pair. For this purpose, a matrix is formed, in which only those cells located to the right of the descending diagonal are filled. In each cell, the expert puts the number of the one of the two characteristics, which in his opinion, based on the results of the consumer survey, is more significant (higher priority). The method is modified so that it is possible to take into account all possible conclusions that experts can come to in the course of their work, in particular, to apply, based on the results of the comparison of characteristics, an assessment of their equivalence.

After processing each matrix filled by the *j*-th expert, the essentiality (priority) for consumers of each characteristic formed according to the requirements of consumers is established based on the results of determining the frequency (quantity) of the predominance of this characteristic over adjacent ones.

$N = 7$ experts took part in the evaluation (pairwise comparison), who directly surveyed and processed the wishes of service users. Each of them independently filled out their separate matrix. An example of a matrix filled out by an expert is shown in Table 3. After processing the data of all matrices, the averaged data for the entire population of experts was obtained.

Table 3. Pairwise comparison matrix filled in by Expert 1

Characteristics according to CR	**Characteristics according to CR**									**E^1 – frequency of predominance of the characteristic in a row over the characteristic in a column**
	RES(1)	**RES(2)**	**RES(3)**	**RES(4)**	**RES(5)**	**RES(6)**	**RES(7)**	**RES(8)**	**RES(9)**	
RES(1)	–	2	1	1	5	1	7	1	1	5
RES(2)	–	–	2	2	2	2	27	2	2	6.5
RES(3)	–	–	–	4	5	36	7	38	3	2
RES(4)	–	–	–	–	45	46	7	4	4	3
RES(5)	–	–	–	–	–	5	7	5	5	3
RES(6)	–	–	–	–	–	–	7	6	9	1
RES(7)	–	–	–	–	–	–	–	7	7	2
RES(8)	–	–	–	–	–	–	–	–	8	1
RES(9)	–	–	–	–	–	–	–	–	–	0
E^2 – frequency of predominance of the characteristic in the column over the charac-teristic in the row	0	1	0	1	2.5	1	5.5	0.5	1	

The processing of these expert assessments is carried out in the following order. After filling in the *j*-th matrix in the rightmost column, the value E^1_{ij} is calculated – the frequency of the predominance of the importance of the *i*-th characteristic in the row over the characteristics in the columns that intersect with this row, as well as the value E^2_{ij} – the frequency of the predominance of the *i*-th characteristic specified in the column, over the characteristics in the rows intersecting with this column (the value of E^2_{ij} is written in the lower row of the matrix). Then, for each i-th characteristic, the value $e_{ij} = E^1_{ij} + E^2_{ij}$ – is obtained – the total frequency of the predominance of materiality.

The results of processing the assessments made by Expert 1 (according to Table 3) of the frequency of predominance of individual characteristics formed by the CR over adjacent ones during the provision of the ES of the spatio-temporal geosystem of the Carpathian mountain forests are presented in the Table 4.

Table 4. Cumulative frequency of predominance of essentiality e_{i1} of each i-th VSC according to Expert 1

No.	The name of the CRC	E^1_{i1}	E^2_{i1}	e_{i1}
1	The physical and geographical characteristics of the territory are close to comfortable ones	5	0	5
2	The level of accessibility to the natural and historical and cultural potential of the territory	6.5	1	7.5
3	The level of costs for access to the service	2	0	2
4	The degree of pollution of environmental components	3	1	4
5	The degree of attractiveness of landscapes	3	2.5	5.5
6	The level of aesthetic properties of objects	1	1	2
7	The presence of objects of world significance entered into the protection lists	2	5.5	7.5
8	The level of recreational development of the territory	1	0.5	1.5
9	The degree of provision of faunal and floristic resources	0	1	1
	Σ	23.5	12.5	36

Taking into account the opinions (total frequency e_{ij} for each characteristic) of all experts, it is possible to determine the average total frequency e_i for the i-th characteristic using the formula:

$$e_i = \frac{\sum_{j=1}^{N} e_{ij}}{N}, \tag{4}$$

where e_{ij} is the total frequency of predominance of characteristics according to the data of an individual expert; N is the number of experts and, accordingly, the pairwise comparison matrix.

After surveying each expert and processing all 7 matrices, a summary table of the prevalence of all characteristics was created (Table 5).

Table 5. Summarized table of the total frequencies of CRC according to the survey of 7 experts

No.	The name of the CRC	e_{i1}	e_{i2}	e_{i3}	e_{i4}	e_{i5}	e_{i6}	e_{i7}	e_i
1	The physical and geographical characteristics of the territory are close to comfortable ones	5	6.5	7	6.5	5	5	5	5.71
2	The level of accessibility to the natural and historical and cultural potential of the territory	7.5	7	7	7.5	7.5	7	6	7.07
3	The level of costs for access to the service	2	2	1.5	2.5	3	2	3	2.29
4	The degree of pollution of environmental components	4	5.5	4	3.5	4	5	4	4.29
5	The degree of attractiveness of landscapes	5.5	4	4	4.5	5	5	6	4.86
6	The level of aesthetic properties of objects	2	3	3	2	2	2	3	2.43
7	The presence of objects of world significance entered into the protection lists	7.5	6.5	6.5	7	7	7	6	6.79
8	The level of recreational development of the territory	1.5	1.5	2	1.5	1.5	2	1	1.57
9	The degree of provision of faunal and floristic resources	1	0	1	1	1	1	2	1
	Σ	36	36	36	36	36	36	36	36

The next step consists in calculating the priority coefficients M_i for each of the identified characteristics. The total number of pairwise comparisons conducted by each expert is:

$$y = \frac{n(n-1)}{2}, \tag{5}$$

where n is the number of characteristics.

Then the priority coefficient of each of the identified characteristics will be found using the formula:

$$M_i = \frac{e_i}{y}, \tag{6}$$

where e_{ij} is the total frequency; y is the total number of pairwise comparisons conducted by each expert.

The obtained data are presented in Table 6.

Table 6. Priority coefficients M_i of each individual CRC

No.	The name of the CRC	Σe_{ij}	e_i	M_i
1	The physical and geographical characteristics of the territory are close to comfortable ones	40	5.71	0.16
2	The level of accessibility to the natural and historical and cultural potential of the territory	49.5	7.07	0.20
3	The level of costs for access to the service	16	2.29	0.06

No.	The name of the CRC	Σe_{ij}	e_i	M_i
4	The degree of pollution of environmental components	30	4.29	0.12
5	The degree of attractiveness of landscapes	34	4.86	0.13
6	The level of aesthetic properties of objects	17	2.43	0.07
7	The presence of objects of world significance entered into the protection lists	47.5	6.79	0.19
8	The level of recreational development of the territory	11	1.57	0.04
9	The degree of provision of faunal and floristic resources	7	1	0.03
	Σ	252	36.01	1

The values of priority M_i from the last column of Table 6 are used in the future to calculate the weighting coefficients of technical characteristics.

Next, the correlations between the characteristics according to CR and TC were determined. During the formation of the list of technical characteristics, each expert determines what are the qualitative and quantitative factors that characterize the ability of the STG to properly provide the necessary ES, and which can be used for its evaluation. The determined TCs are shown in Table 7.

Table 7. TC of cultural ESs of the spatio-temporal geosystem

No.	The name of the technical characteristic	Designation
1	Attractiveness of cultural ESs (qualitative characteristics)	Sp(1)
2	Contrast of the territory of the public housing development (qualitative characteristic)	Sp(2)
3	The number of cultural objects (quantitative characteristics)	Sp(3)
4	Originality (uniqueness) of objects (qualitative characteristics)	Sp(4)
5	Diversity of natural recreational resources (qualitative characteristics)	Sp(5)
6	Use of traditions and tourist and recreational heritage of the STG region (qualitative characteristics)	Sp(6)
7	Availability of nature reserve fund objects (qualitative characteristics)	Sp(7)
8	Compartmental mosaicity of phytocenosis on the territory of STG (qualitative characteristics)	Sp(8)

Next, the results of the assessment by experts of the degree of correlation of the characteristics determined according to the requirements of the consumers – CRC, and the technical characteristics of the cultural ES of STG are presented. For this purpose, each expert uses a universal scale to assess the mutual influence of TC and CRC. The experts were asked to combine the vague linguistic variable "correlation coefficient of CRC and TC" with a specially developed set of linguistic terms. The developed totality most fully covers the gradation of possible evaluations and makes it possible to effectively move from vague to clear evaluations using the membership function.

Table 8 presents the linguistic terms of the variable "correlation coefficient of CRC and TC" and their corresponding fuzzy numerical values.

Table 8. Linguistic terms and their corresponding fuzzy values for determining the correlation coefficients of CRC and TC

	A linguistic term	Fuzzy numerical value
(F)	Full	(0.95, 1.00)
(VH)	Very high	(0.85, 0.90, 0.95)
(H)	High	(0.75, 0.80, 0.85)
(NMNH)	Neither medium nor high	(0.65, 0.70, 0.75)
(AA)	Above average	(0.55, 0.60, 0.65)
(M)	Medium	(0.45, 0.50, 0.55)
(BA)	Below average	(0.35, 0.40, 0.45)
(NMNL)	Neither medium nor low	(0.25, 0.30, 0.35)
(L)	Low	(0.15, 0.20, 0.25)
(VL)	Very low	(0.05, 0.10, 0.15)
(O)	Missing	(0.00, 0.05)

Table 9 shows an example of the assessment of correlations between TC and CRC by one expert using the scale of linguistic terms of the variable "correlation coefficient" given in Table 8.

Table 9. An example of linguistic assessments by an individual expert of the degree of correlation between TC and CRC

	Sp(1)	Sp(2)	Sp(3)	Sp(4)	Sp(5)	Sp(6)	Sp(7)	Sp(8)
RES(1)	O	C	NMNL	HC	HC	VL	O	O
RES(2)	O	VL	NMNL	NMNL	VL	AA	VL	H
RES(3)	H	NMNL	VL	O	O	O	O	O
RES(4)	VL	L	AA	VH	H	H	AA	O
RES(5)	F	AA	VL	NMNL	NMNL	BC	NMNL	NMNL
RES(6)	NMNL	NMNL	NMNL	C	H	VL	VL	VH
RES(7)	VL	H	VH	L	O	O	C	VH
RES(8)	L	BA	BA	O	O	O	O	NMNL
RES(9)	VH	VH	C	VL	O	O	O	VL

Since the presence of correlations and the degree of correlation between consumer requirements and technical characteristics are the result of the interaction of a set of various factors, among which a significant number may be random, based on the central limit theorem, as well as the experience of applying correlation coefficients in other areas, it can be assumed, that the probability distribution function of correlation degrees is well described by a Gaussian curve. That is, most of the correlation relations acquire values that are in the interval ($0{,}3 < r < 0{,}7$), which means that they are close to the middle of the range.

The results of processing the fuzzy set of all verbal ratings obtained from 7 experts using the data in Table 8 and the proposed membership function are presented in Table 10.

Defuzzification was performed using the method of the center of gravity according to the formula:

$$\overline{r_{ij}} = \frac{\sum_{k=1}^{7} \left(r_{ij}\right)_k \mu\left(r_{ij}\right)_k}{\sum_{k=1}^{7} \mu\left(r_{ij}\right)_k},$$

where $\overline{r}_{ij}$ is the average weighted coefficient of pairwise correlation between the *i*-th characteristic of the CR and the *j*-th TC, determined according to the assessments of 7 experts; $(r_{ij})_k$ – fuzzy estimate of the pairwise correlation coefficient between the *i*-th characteristic of the CR and the *j*-th TC, determined by the *k*-th expert; $\mu(r_{ij})_k$ is the value of the membership function for the fuzzy estimation of the pairwise correlation coefficient determined by the *k*-th expert.

Table 10. The results of the calculation of the degree of correlation between TC and CRC

	Sp(1)	**Sp(2)**	**Sp(3)**	**Sp(4)**	**Sp(5)**	**Sp(6)**	**Sp(7)**	**Sp(8)**
RES(1)	0.08	0.41	0.33	0.39	0.37	0.08	0.05	0.00
RES(2)	0.00	0.04	0.59	0.31	0.07	0.61	0.45	0.86
RES(3)	0.21	0.69	0.07	0.00	0.00	0.00	0.05	0.02
RES(4)	0.13	0.59	0.10	0.85	0.81	0.68	0.30	0.71
RES(5)	1.00	0.61	0.05	0.55	0.79	0.57	0.29	0.70
RES(6)	0.25	0.40	0.62	0.48	0.85	0.10	0.07	0.88
RES(7)	0.12	0.60	0.95	0.24	0.00	0.05	0.55	0.91
RES(8)	0.20	0.38	0.44	0.00	0.00	0.09	0.40	0.28
RES(9)	0.91	0.78	0.55	0.11	0.00	0.00	0.10	0.12

Table 11 presents the results of the determination of TC weight.

Table 11. "House of quality" for determining the importance of TC cultural ES of the Carpathian mountain forests

Charac-teristics according to the consumer requi-rements – CRC	**The priority of each consumer requi-rement is *Im***	**A set of technical characteristics {TX_j} and their corresponding quantitative values q_j**							
		Sp(1)	**Sp(2)**	**Sp(3)**	**Sp(4)**	**Sp(5)**	**Sp(6)**	**Sp(7)**	**Sp(8)**
		q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8
RES(1)	0.16	0.08	0.41	0.33	0.39	0.37	0.08	0.05	0.00
RES(2)	0.20	0.00	0.04	0.59	0.31	0.07	0.61	0.45	0.86
RES(3)	0.06	0.21	0.69	0.07	0.00	0.00	0.00	0.05	0.02

Characteristics according to the consumer requirements – CRC	The priority of each consumer requirement is *Im*	A set of technical characteristics $\{TX_j\}$ and their corresponding quantitative values q_j							
		Sp(1)	Sp(2)	Sp(3)	Sp(4)	Sp(5)	Sp(6)	Sp(7)	Sp(8)
		q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8
RES(4)	0.12	0.13	0.59	0.10	0.85	0.81	0.68	0.30	0.71
RES(5)	0.13	1.00	0.61	0.05	0.55	0.79	0.57	0.29	0.70
RES(6)	0.07	0.25	0.40	0.62	0.48	0.85	0.10	0.07	0.88
RES(7)	0.19	0.12	0.60	0.95	0.24	0.00	0.05	0.55	0.91
RES(8)	0.04	0.20	0.38	0.44	0.00	0.00	0.09	0.40	0.28
RES(9)	0.03	0.91	0.78	0.55	0.11	0.00	0.00	0.10	0.12
		Calculated weight of each technical characteristic							
		0.2466	0.4457	0.4515	0.3804	0.3326	0.3106	0.3031	0.5987
		Normalized weightings of technical characteristics – w_j							
		0.0803	0.1452	0.1471	0.1239	0.1084	0.1012	0.0988	0.1951

After obtaining the normalized TC weighting values, which are actually the weighting coefficients of each technical characteristic of the cultural ES of STG, it is possible to obtain qualitative assessments of various spatio-temporal geosystems. As it was said earlier, it is proposed to consider 3 conditional STG – A, B, C, which provide cultural ecosystem services to consumers as service providers. In order to form linguistic assessments for each TC, experts were offered a different term-set, which makes it possible to combine technical characteristics that are different in their physical nature (Table 7). The used linguistic terms and their corresponding fuzzy numbers are listed in Table 12.

Table 12. Linguistic terms and their corresponding fuzzy values for obtaining expert evaluations of TC

	Linguistic term	Fuzzy number
(VH)	Very high	(8, 9, 10)
(H)	High	(6, 7, 8)
(M)	Medium	(4, 5, 6)
(L)	Low	(2, 3, 4)
(VL)	Very low	(0, 1, 2)

When nothing is known about the nature of changes in TC values and there is a need to combine heterogeneous TCs, it is advisable to use the triangular membership function [25, 26]. In this case, the vague event is described by the parameters α, β, γ – α is the smallest possible value, β is the most promising value (the value on the numerical scale that best characterizes the corresponding meaning of the linguistic term) and γ is the most possible value.

The results of evaluation by a separate expert for all TCs of each of the three compared spatio-temporal geosystems are shown in Table 13.

Table 13. An example of linguistic assessments by an individual expert of TC values of spatio-temporal geosystems A, B, C

	Sp(1)	Sp(2)	Sp(3)	Sp(4)	Sp(5)	Sp(6)	Sp(7)	Sp(8)
A	VH	M	L	H	M	H	H	L
B	M	VH	H	VH	M	H	H	M
C	L	H	L	VH	H	M	VH	VL

Defuzzification contains a five-step algorithm [25].

1. Normalization. We determine the range of values that a fuzzy variable can take among the estimates of the j-th TC by all $l = 1, 2, \dots k, \dots,$ seven experts:

$$\Delta = \max \gamma_j - \min \alpha_j. \tag{7}$$

We perform the normalization of each evaluation parameter of the k-th expert:

$$\alpha^N_j = (\alpha_j - \min \alpha_j) / \Delta, \tag{8}$$

$$\beta^N_j = (\beta_j - \min \beta_j) / \Delta, \tag{9}$$

$$\gamma^N_j = (\gamma_j - \min \gamma_j) / \Delta. \tag{10}$$

2. We calculate the left (l) and right (r) normalized values:

$$\alpha l_j^N = \frac{\beta_j^N}{1+\beta_j^N - \alpha_j^N}, \tag{11}$$

$$\gamma r_j^N = \frac{\gamma_j^N}{1+\gamma_j^N - \beta_j^N}. \tag{12}$$

3. We calculate the total normalized clear value:

$$N_j = \frac{\alpha l_j^N \left(1-\alpha l_j^N\right) + \left(\gamma r_j^N\right)^2}{1-\alpha l_j^N + \gamma r_j^N}. \tag{13}$$

4. We calculate the exact value of the j-th TC of the k-th expert:

$$q_j = \min \alpha_j + \Delta N_j. \tag{14}$$

5. We combine clear values in the form of an average according to the estimates of all l experts:

$$\overline{q}_j = \frac{1}{l}\left(q_j^1 + q_j^2 + \dots + q_j^k + \dots + q_j^l\right). \tag{15}$$

The results of defuzzification of fuzzy linguistic evaluations obtained from all 7 experts for each technical characteristic and for each studied STC are summarized in Table 14.

Table 14. Results of the evaluation of spatio-temporal geosystems A, B, C by all experts for each TC

	Sp(1)	Sp(2)	Sp(3)	Sp(4)	Sp(5)	Sp(6)	Sp(7)	Sp(8)
A	8.531	5.501	3.035	6.174	4.411	6.907	7.181	2.891
B	6.282	8.147	6.168	7.551	5.991	7.912	6.921	5.750
C	3.825	6.011	3.312	7.276	8.172	4.553	9.573	1.101

Formula (3) was used to obtain the final assessment – to compare the spatio-temporal geosystems A, B, C, which provide cultural ESs.

Table 15 shows the final results of the evaluation of each spatio-temporal geosystem providing cultural ESs.

Table 15. Qualitative evaluations of three STGs providing cultural ESs

Spatio-temporal geosystem	Assessment
A	5.1458
B	6.8414
C	5.0759

Conclusions

The complexity and multifacetedness of the components of the tourist and recreational potential of the spatio-temporal geosystem and the possibility of its use for the development of tourist activities, in particular in the Carpathian mountain forests, require the formation and improvement of universal methodological approaches to the comprehensive assessment of resources, which will make it possible to make balanced decisions for socio-economic development of the region.

An alternative comprehensive method of assessment and selection of a provider of cultural ecosystem services for recreation and tourism, which can be different spatio-temporal geosystems, is presented, and which maximally takes into account all possible significant factors that determine the reliability of a qualitative assessment. Based on the calculations, it is established that supplier B is the best choice and supplier C is the worst. Also, based on the results of using the method, it is possible to control the critical success factors for the provider of ecosystem services and to determine the weak and strong links of both a certain STG and the market conditions of ecosystem services.

The study made it possible to assume that various types of resources of the spatio-temporal geosystem can be used to create a recreational-tourist product, in particular landscape complexes, compartments and their horizontal heterogeneity – mosaicity, faunal and floristic resources, objects of the nature reserve fund, historical and cultural objects, traditions and tourist and recreational heritage of the region, etc. At the same time, in order to meet the needs of different categories of tourists and vacationers, the use of resources of the spatio-temporal geosystem should be differentiated in accordance with the emerging needs and demands of consumers.

As the approbation of the method of complex qualitative assessment of the tourist and recreational potential on the example of the STG of the Carpathian Mountain Forests showed, the proposed approach takes into account not only the spatial features of the territory and the elements of its potential, but also the evaluation criteria important for solving organizational and economic issues of tourism management. The approach makes it possible to combine various methods of evaluating tourist resources, to adjust criteria and technical characteristics, weighting factors and quality indicators.

In conclusion, it should be added that the systematic solution of problems related to the use of the tourist and recreational potential of the public housing estate for the implementation of cultural ecosystem services requires the improvement of legislation in the field of tourism, the formation of institutional conditions for its sustainable development, the creation of favorable conditions for the work of small businesses, the provision assistance in the training of personnel for the tourism industry and stimulation of demand for the domestic tourism product.

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Sustainable development – state and prospects (SDEV'2022)
Mirosław Borkowski, Oleksandr Moroz, Mykhailo Paslavskyi (red.)
Wydawnictwo GSW • Gdańsk 2023 • ISBN 978-83-66270-30-5

UDC 504.064.2.001.18

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The features of creating a geographic information system for environmental monitoring of a mining and chemical enterprise in the post-liquidation period

Abstract
The mining industry is a source of significant anthropogenic impact on natural components. The activity of the mining and chemical enterprise leads to the activation of dangerous natural and man-made processes, which cause disturbance of land and degradation of landscapes, pollution of the atmosphere and water environment, impoverishment of the plant and animal world, and endanger the life and health of people. These impacts can be implemented at all stages of mining, from the research of mineral resources to the closure of an enterprise. The purpose of the work is to consider the features of creating a geographic information system for environmental monitoring of a mining and chemical enterprise in the post-liquidation period. In the research on the example of State Enterprise (SE) "Rozdil Mining and Chemical Enterprise (MCE) »Sirka«" one of the main parts of the system of geoinformation system of ecological monitoring – remote ecological monitoring is carried out. The process of liquidation of the mining and chemical enterprise has the following stages: monitoring and forecasting of hazardous phenomena which may arise after the exploitation of deposits and activities of the enterprise; assessment of environmental risk for the population and property; comparison of the cost of active and passive methods for eliminating risk; substantiation of rational use of renewable territories; the development of the necessary measures for the prevention of environmental hazards and the preparation of areas for economic use. The geoinformation monitoring system creation is the first and the main stage of the process of liquidation of the mining and chemical enterprise. To do this, it is necessary to create a database of geological and ecological indicators, which will allow to analyze of factors in detail, predict the pollution of the territory, to construct a spatial model of pollution, in the presence of a cartographic database of test points to construct timetables for changes in time of any analyzed values. The impact of the mining and chemical enterprise on the state of pollution of the environment was assessed in the paper. The need to design an informational and analytical system for monitoring the territory of SE "Rozdil MCE »Sirka«" at the stage of the liquidation was proved. It was established that it is necessary to create a geoinformation monitoring system, which will increase the ecological safety of the enterprise territory and the surrounding settlements. Also, such a system will allow early warning of negative environmental changes in the enterprise territory or surrounding territories after the completion of mining operations.

Introduction

Mining landscapes that have been formed in Ukraine are characterized by a complex internal structure. Their peculiarities depend on the method of extraction, the technology of extraction of raw materials, terrain, hydrological regime and soils of exhausted areas, the nature of the surrounding landscapes. For the most part, these are azonic landscape complexes, in the structure of which there are 3 types: quarry-cavernous, peat-wetlands, slag heap and pseudo karst.

The process of functioning of the ecosystem "mining enterprise – the environment" can be divided into the following stages: design and implementation of the project, optimal operation of the mining enterprise, cessation of mining activities and liquidation of the enterprise, and the after-liquidation period.

There are three possible ways of liquidation a mining enterprise:

1. Planned liquidation of the enterprise, following the plan of development of the enterprise in case of the completion of the stock of the exploited field.
2. Emergency liquidation resulting from sudden decisions on the elimination connected with the catastrophe, economic decline or other causes.
3. The temporary closure of mines, quarries is associated with economic and technological problems that prevent the continuation of mining of minerals and activities. During partial liquidation work it is necessary to consider the possibility of re-exploitation of the deposit [1, 2].

Liquidation of Ukrainian mines and quarries usually is the emergency. The liquidation program is often created after the decision to stop the activity. The consequence of the existing approach to solving the problem of liquidation of an enterprise is the problem of proper organization of rehabilitation works and the danger of the development of negative anthropogenic changes.

It is necessary to carry out the reclamation of postmining landscapes in liquidation of a mining enterprise: to implement a complex of engineering, mining, reclamation, biotic, sanitary and hygienic and other measures aimed at the return of areas affected by the industry in various types of nature management: agricultural, forestry, recreation, etc. The development of deposits of minerals cannot begin until the project of reclamation of disturbed landscape systems is developed.

Until today, reclamation was considered the only effective measure to address the issues of rational use of natural resources and nature conservation.

All mining areas and objects, where changes in the thickness of sediments, relief, soil and vegetation are subject to reclamation. Monitoring is one of the main stages of the reclamation and liquidation of the mining complex [3-9].

Analysis of the literature

Problems of the disturbed territories as a result of extraction of minerals, studying of a technogenic landscape, a condition of a ground cover were investigated by scientists among whom: O.Ia. Adamenko, B.I. Volosetskyi, A.M. Haidin,, I.I. Zozulia, M.S. Malovanyi, O.H. Maryskevych, L.P. Markovych, L.V. Motorina, R.M. Panas, H.I.

Rudko, Shkitsa L.Ie., A. Gąsiewicz, M. Ossowska and others. Problems of studying and researching the land cadastre were covered in research and publications of M.H. Lykhohrud, A.A. Liashchenko, A.H. Martyn, A.M. Mukhovykov, L.M. Perovych, O.S. Petrakovska, M.H. Stupen, R.B. Taratula, A.M. Tretiak, P.H. Cherniaha and others. The problems of improving the ecological condition, landscaping of disturbed areas, development of scientifically sound recommendations and proposals for the effective use of disturbed lands remain unresolved. The solution of these problems significantly depends on the monitoring of the state of the environment in the area of mining and chemical works, which will allow to create an objective and reliable model of the state of the environment and respond in a timely manner to adverse changes [9].

Topicality

SE "Rozdil MCE »Sirka«" is in the West of Ukraine (Lviv region). Large-tonnage wastes like phosphogypsum (over 3 million tons) were formed on its territory in connection with the production of mineral fertilizers for 22 years (from 1974 to 1996), and there are about 60 million tons of sulfur ore tailings on the territory of the enterprise. In addition, on the territory of the enterprise 17,195 tons of "MG" type modifiers, made from neutralized tar residues and residues boiler anhydrite maleic acid were imported from Hungary. The wastes have heavy metals that migrate in the soil and the water environment. Currently, the enterprise does not work and is in the stage of liquidation. It poses an environmental hazard to the Dniester River and surrounding settlements (Fig. 1) [10-12].

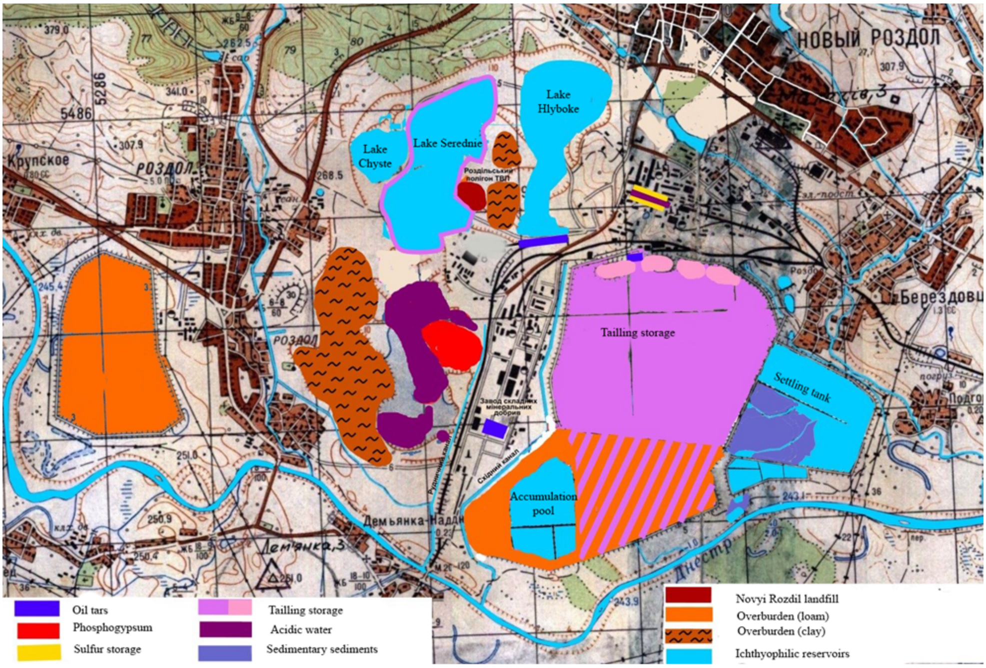

Fig. 1. Sources of ecological danger of SE "Rozdil MCE »Sirka«"

In 2021 we conducted summer and autumn testing of the largest reservoirs in the area of influence of SE "Rozdil MCE »Sirka«" – Lakes Serednie, Hlyboke, Kysle and Chyste, located near the storage sites of industrial waste (sulfur and ultraacid water in sulfur composition, sulfur flotation phytophobia), tars, solid household waste) and water from which flows into the transboundary Dniester River through the Hirnychyi Canal.

The conducted researches have established that the main sources of water pollution in the zone of influence of SE "Rozdil MCE »Sirka«" are:

1. Tailings No. 1 and 2, where the tailings of sulfur ore beneficiation of different fractions from the sand dimension in the burts to the siltstone size in the beach part of the tailings and the clay fraction in the core are stored. Waste is a source of hydrogen sulfide water with a salinity of about 3000 mg/dm^3 and an unpleasant odor.
2. Phosphogypsum dump, with a total volume of 3 million m^3 and a settling tank of acidic waters around it. Leaching of acids from the phosphogypsum heap leads to the formation of acidic waters enriched in heavy metals. This is the largest source of pollution of the hydrosphere.
3. The open composition of lump sulfur, which is a source of ultra acid water in the aquatic environment.
4. Three tar landfills, one of which is on the shores of Lake Hlyboke, which are a source of inflow of petroleum products and acidic waters.
5. Novyi Rozdil landfill on the shores of Lake Serednie, which is a source of leachate and microplastics.

Hlyboke Lake is connected to the Dniester River by a canal. There are the results of hydrochemical studies for 2021 at sampling points (Table 1):

1. The Dniester River, 50 m below the discharges from Rudnychyi Canal.
2. The Dniester River near the Rozvadiv village, above the discharges of SE "Rozdil MCE »Sirka«".
3. The Dniester River near the Berezyna village, above the discharges of SE "Rozdil MCE »Sirka«".
4. The Dniester River, below the discharges of SE "Rozdil MCE »Sirka«".

The ecological situation in the Dniester River basin over the past 15-20 years under the influence of anthropogenic factors has become a crisis. Downstream are the water intakes of many cities in Ukraine and Moldova, and since the Dniester is a river of international importance, its pollution can lead to interstate conflicts and significant financial sanctions. Therefore, comprehensive operational environmental monitoring in the area of mining and chemical enterprises is extremely important.

The territories of the mining and chemical enterprises, which are in the stage of liquidation, are subject to reclamation that is the restoration of valuable properties, following the existing legislation. The industrial enterprises that destroyed these lands handle carrying out reclamation works, and the cost of reclamation should be included in the cost price of the finished product. General requirements for soil remediation in Ukraine are regulated by GOST (state standard) 1-7.5.3.04-83.

Table 1. Chemical analysis of water in the territory of influence of SE “Rozdil MCE »Sirka«”

Parameter	**1**	**2**	**3**	**4**
Mineralization [mg/dm^3]	750.5	777.7	745.5	848.9
Dry residue [mg/dm^3]	360	430	410	530
pH	8.1	7.9	8.0	6.8
Chemical Oxygen Consumption [mg/dm^3]	4.0	4.0	4.0	4.0
Dissolved O_2 [mg/dm^3]	8.0	8.0	8.0	8.0
Fe common [mg/dm^3]	0.425	0.425	0.425	0.4
Conductivity [mS]	0.74	0.80	0.77	0.91
ppt	0.38	0.40	0.40	0.42
General hardness [mg-eq/l]	10.5	10.5	10.5	10.5

Sequence of reclamation works technical reclamation, then biological. Technical reclamation is to prepare disturbed lands for further use in the household. Biological reclamation involves measures that promote the improvement of physical and agrochemical properties of soils on reclaimed lands (liming, sanding, mineral, organic, ash, slag fertilizing, etc.) [13].

There are such types of technical reclamation:

- agricultural (preparation of land for use as agricultural land);
- forestry (preparation of land for forest plantation);
- water management (preparation for the creation of a reservoir on the territory of mining complex);
- construction (preparation of land for industrial and civil construction);
- recreation (preparation of land for recreation facilities);
- sanitary-hygienic (preservation of disturbed lands if their reclamation for another purpose for some reasons is not feasible).

Forestry reclamation is carried out where there is a possibility to restore the forest area due valuable breeds of trees. Its cost and requirements for the agrochemical characteristics of the reclaimed soils are lower than during agricultural reclamation. Water management reclamation is carried out in spent quarries, which often fill groundwater. Recreational reclamation is carried out not far from cities and large settlements to create recreation areas for the population. Mostly it is combined with water management and forestry reclamation. Sanitary hygienic reclamation is used in areas where harmful substances are stored to prevent their harmful effects on the environment.

The volume of work of the technical stage of reclamation depends on the condition of the affected areas and the type of planned use. Plots prepared for eligibility for non-agricultural use (for parks, reservoirs, industrial and municipal construction, etc.) are transferred to the relevant organizations following the established procedure. Areas intended for agriculture and forestry, after the technical stage of reclamation, shall be returned to or transferred to the relevant agricultural or non-agricultural enterprises for the purpose of biological reclamation and further intended use.

In the mining industry, the reclamation of the territory is a complex system of measures to reduce or cut the direct and indirect action of mining activities on the environment. No less important is its monitoring stage.

Environmental monitoring of the territory of SE "Rozdil MCE »Sirka«" involves multidisciplinary research on the state of soils and water bodies, tar residues, phosphogypsum dumps, and the evaluation of geological and geophysical processes, in particular environmental degradation.

The open pit mining is characterized by such kinds of negative changes in the environment:

- gas polluted atmospheric pollution during explosive mining operations in quarries, airborne exhaust gases of technological and transport vehicles, formation of mineral dust during blasting, crushing, loading and transportation of rock masses;
- changes in the water regime of groundwater (closest to the surface of the horizons) and surface water due to the drainage and drainage from the mining;
- pollution of soil and surface water by quarry waters, formation of filtrate during water erosion of waste dumps;
- violation of soil-vegetation cover and use of land under mining and dumps.

The process of liquidation of the mining and chemical enterprise has the following stages:

1) monitoring and forecasting of hazardous phenomena which may arise after the exploitation of deposits and activities of the enterprise;
2) assessment of environmental risk for the population and property;
3) comparison of the cost of active and passive methods for cutting risk;
4) substantiation of rational use of renewable territories;
5) the development of the necessary measures for the prevention of environmental hazards and the preparation of areas for economic use.

The existing approaches to the reclamation of postmining landscapes are often outdated. The results of various studies and the analysis of the experience of implemented projects allow us to state that in the conditions of reclamation and phytomelioration of postmaying geosystems in areas of development of various types of minerals (coal, oil, sulfur, salts, etc.) for the purpose of their further agricultural use will never be redeemed. Alignment and terracing of slopes with the application of a fertile layer of soil compositions are (costly) expensive and ineffective optimization measures. For industrial forestry it is also necessary to level the surface and ensure the permeability of the area and proper microclimate, which also requires significant costs. In addition, there is the problem of large-tonnage wastes in the mining area, as well as pollutants in the environmental elements, which also needs to be solved.

The liquidation project should contain an environmental analysis of the enterprise activities, environmental forecasting, a system for monitoring the territory during the liquidation and after the elimination period, and it should be completed the formation of the information system of the ecological state of the territory of the influence of enterprise with the provision of free access to information [12].

The main threats to be considered at the stage of the completion of the exploitation of the deposit are chemical pollution of soils, waters and violations of the ecological stability of the territory. Attempts to systematize and find selected problems are solved in monitoring and forecasting negative impacts of mining activities. The systematic recording of indicators and changes in individual environmental components is the diagnosis and forecasting of existing conditions, i.e., monitoring. Monitoring should be carried out not only during the first stage, but also during the liquidation and reclamation of the enterprise. The object of research may be the entire territory of the mining industry or part of it, which is actively exposed to the mining activity or the results of this activity. On the territory of SE "Rozdil MCE »Sirka«", monitoring objects can be large-tonnage wastes (dump of phosphogypsum, tailings storages, place, where is situated the tar modifier), soils, water objects, geophysical changes. It is necessary for the implementation of the main monitoring tasks: a set of constituent systems for registering the state of the selected characteristics of the environmental elements that control; analysis of the obtained results, their transformation and distribution; use of the generated database. At each of these stages, there is a need to adapt the accepted method to the specificity of the phenomenon being monitored, the properties of the environmental element under the influence of this phenomenon. All this requires the assessment of technical and analytical capabilities, in this connection, the development of monitoring system design and planning is essential, which would provide the most probable assessment of the behavior of the selected phenomenon with the least financial cost [14-16].

Various types of sensors can be used to monitor the mining industry. Examples are enzyme-based fluorescent biosensors based on enzymes. This sensor type is commonly used in clinical diagnostics, environmental protection, and the defense industry, and also in those areas where rapid and reliable measurements are required.

Initial data for monitoring are maps of the location of the objects of technological influence, which are mining, zones of accumulation of industrial waste with brief information of each of them (height (m), width (m), area (m^2), volume of composite rock (m^3)). The result of the research is the maps with the allocation of zones of technogenic impact of each source. This information is an integral part of the information system of the territorial complex for the period of completion of operation. Part of the information will present the existing ecological losses of the natural and man-made system, for example, the distributed zones of acidification (depth, area, distribution intensity, habitats of soil pollution, ground waters, fallings (depth (m), diameter (m), slope angle (degree), area (m^2)). In the absence of adequate and timely financing of reclamation works, the issue of studying the processes of self-rehabilitation of environmental elements remains to be necessary: the hydrogeological regime of the region, the activation of off-hazardous processes. Water quality control is still a priority task at the period of postliquidation [14, 17-20].

Research results and discussion

Today, geographic information systems (GIS) are the most effective tool for understanding and describing a constantly changing geographical environment. These systems are used to solve many practical problems related, one way or another, to spatial distribution data, which are used to ensure environmental security and sustainable development of regions. Geographic information systems can be used in areas such as:

- analysis of environmental monitoring data;
- creation of digital maps showing the state of the environment;
- analysis of changes that have occurred in the study region;
- forecasting the consequences of certain economic decisions.

Using data from the website https://earthengine.google.com/timelapse, which provides space images of the territory of SE "Rozdil MCE »Sirka«" from 1985 to 2018, we analyzed the natural state and negative environmental changes of the study area due to anthropogenization. Google Earth Engine is a geospatial processing service. With Earth Engine, we can perform geospatial processing at scale, powered by Google Cloud Platform. Timelapse is a global, zoomable video that lets you see how the Earth has changed over the past 34 years. It is made from 35 cloud-free annual mosaics, one for each year from 1984 to 2018, which are made interactively explorable by Carnegie Mellon University CREATE Lab's Time Machine library, a technology for creating and viewing zoomable and pannable timelapses over space and time. Using Earth Engine, the website combined over 15 million satellite images acquired over the past three decades by 5 different satellites. Most of the images come from Landsat, a joint USGS/NASA Earth observation program that has observed the Earth since the 1970s. For 2015 through 2018, the website combined Landsat 8 imagery with imagery from Sentinel-2A, part of the European Commission and European Space Agency's Copernicus Earth observation program. Exploring Timelapse it could be search, pan, or zoom around. Timelapse is an example that illustrates the power of Earth Engine's cloud-computing model, which enables users such as scientists, researchers, and journalists to detect changes, map trends, and quantify differences on the Earth's surface using Google's computational infrastructure and the multi-petabyte Earth Engine data catalog.

As can be seen from the space photos, Lake Serednie began to form in 1989. Lake Chyste began to form in 1997, and Lake Hlyboke – in 2003. In 2009, the level of flooding of Lake Hlyboke reached 252.4 m. Compared to 1989, in 10 years Lake Serednie has increased its area by about 2 times. Since 2003, the area of Lake Hlyboke has tripled (Fig. 2-4) [21, 22].

Fig. 2. Space photos of SE “Rozdil MCE »Sirka«”, 1985-1997

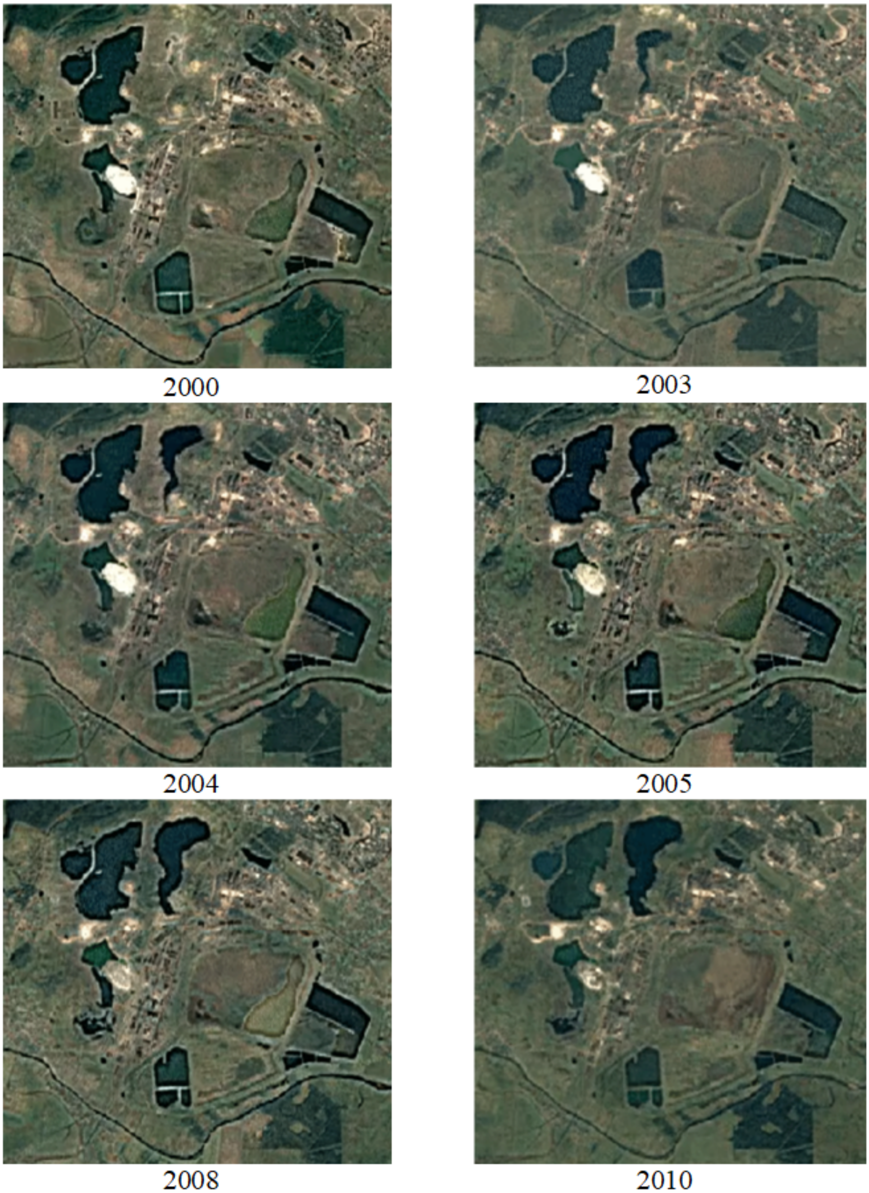

Fig. 3. Space photos of SE "Rozdil MCE »Sirka«", 2000-2010

By analysing space images, it was found that the area of lump sulfur residues over the past 12 years has decreased significantly (Fig. 5).

Due to the combustion of elemental sulfur, sulfur dioxide is formed. Combustion areas are marked by a molten surface, and the storage area of lump sulfur over the past 12 years, according to the analysis of space images has decreased significantly. Decrease in the storage area of lump sulfur due to its burning over the last 12 years, set up based on the analysis of space images of 2004 and 2016.

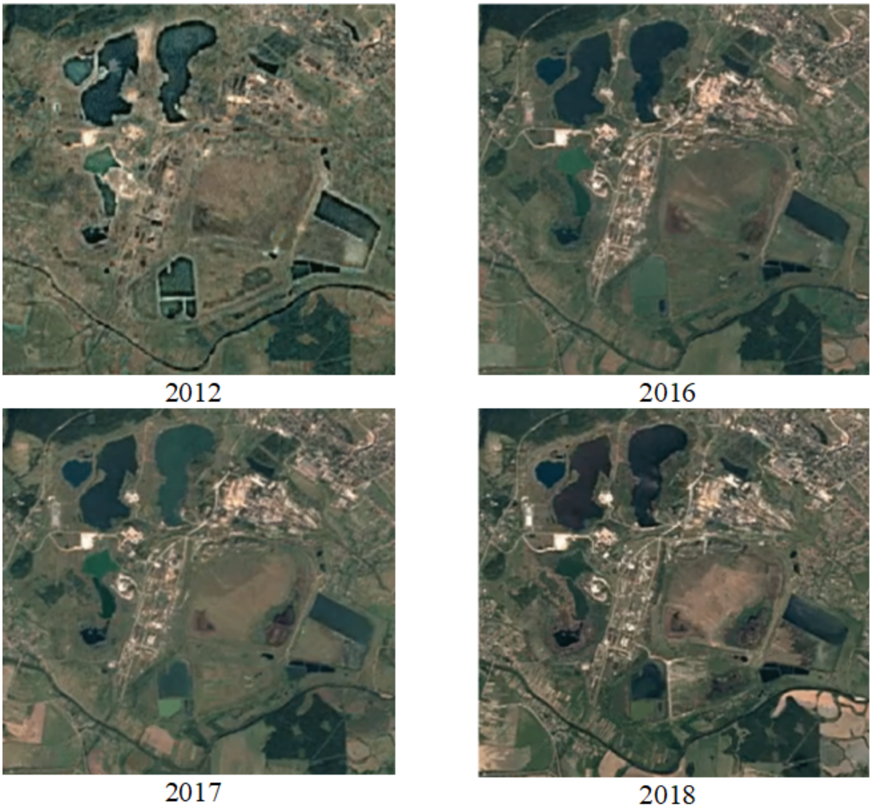

Fig. 4. Space photos of SE “Rozdil MCE »Sirka«”, 2012-2018

Fig. 5. Space photo of lump sulfur storage 2004 (left) and 2016 (right)

Conclusions

The ecological balance of the territory was disturbed due to the fact that the elimination of negative technical manifestations of the enterprise has long been considered unprofitable. Therefore, it is advisable to establish a general practice aimed at restoring degraded areas.

The impact of the mining and chemical enterprise on the state of environmental pollution: soils, aquatic environment and the state of industrial waste management is estimated. The necessity of building a geoinformation system for monitoring the territory of SE "Rozdil MCE »Sirka«" at the stage of liquidation is substantiated. It is established that creation of this system of ecological monitoring will allow to increase ecological safety of the territory of the enterprise and adjacent settlements. Also, such a systematic approach to ensuring or improving environmental safety will prevent negative changes in the enterprise or surrounding areas after the completion of mining. Monitoring is one of the main stages of the process of liquidation and reclamation and should be carried out at all stages of liquidation. In addition to the monitoring system in the process of liquidation and in the post-reclamation period, the liquidation project should include an environmental analysis of the enterprise activities, environmental forecasting. This should be completed by the formation of the information system of the ecological state of the territory of the enterprise influence with the provision of free access to information. Compliance with all conditions will allow increasing the ecological safety of the territory and react in a timely manner to unusual ecological situations, which will reduce environmental, social and economic losses.

By analyzing space images, it was found that the area of lump sulfur residues has decreased significantly over the past 12 years. It was analyzed the natural state and negative environmental changes of the study area due to antropogenization.

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Sustainable development – state and prospects (SDEV'2022)
Mirosław Borkowski, Oleksandr Moroz, Mykhailo Paslavskyi (red.)
Wydawnictwo GSW • Gdańsk 2023 • ISBN 978-83-66270-30-5

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The influence of technogenic objects on the quality of atmospheric air

Abstract
Today, the issue of air pollution is extremely important for scientists, because pollution in cities and industrial regions is at a high level. Dangerous amounts of pollutants in the air pose a significant risk to the general condition of the human body. With the beginning of the industrial revolution, the amount of waste increased, the amount of discharges into water bodies and emissions of pollutants into the atmosphere increased significantly. Over time, it gained a planetary scale, which attracted the attention of mankind. There has been a question of global warming and climate change, littering the planet and polluting all areas of the environment. Therefore, assessing the extent of air pollution in cities and regions is a pressing issue today. The aim of the work is to establish the scale and chemical composition of air pollution by industrial facilities on the example of Kyiv region; development of environmental measures to minimize the negative anthropogenic impact on the environment. The analysis of the state of air pollution of the studied region is carried out. Based on the analysis, it was established that the main sources of air pollution with harmful substances in the region are vehicles and industrial enterprises. The key polluters of Kyiv region are enterprises of ferrous metallurgy, energy and production of chemistry and petrochemistry. The sources of air pollution are mobile and stationary sources. It was found that in 2020, the largest emissions from stationary sources were sulfur dioxide, as well as a significant amount of solid particles and nitrogen dioxide. In the period from 2017 to 2019, the amount of major pollutants in the air from stationary sources of pollution has increased significantly. If 2018-2019 have approximately similar values, except for the amount of emissions of persistent organic pollutants and polyaromatic hydrocarbons, then separately for 2017 and 2019 there is an increase in emissions of major pollutants almost twice. The most polluted cities and districts in the study area were identified. The main reason for the pollution of such cities and districts is the high level of man-made load and the number of enterprises that emit into the atmosphere. The main causes of air pollution by enterprises are the use of outdated technologies, most of which do not meet modern environmental requirements, as well as the low level of operation of dust collection equipment. Trypillya TPP is the largest stationary source of pollution in the Kyiv region and, at the same time, the largest polluter, as it operates on coal. Emissions of sulfur dioxide from Trypillia TPP in 2017-2019 almost doubled, as well as almost doubled emissions of carbon monoxide, suspended solids and nitrogen compounds. This is due to unsatisfactory and inefficient operation of treatment equipment and increased intensity of thermal power plant operation. With the use of solid fuel from thermal power plants, parts of ash that are not captured by gas treatment plants, unburned fuel residues, sulfur dioxide, nitrogen and carbon oxides are released into the atmosphere. Ways to reduce emissions from fuel combustion at a thermal power plant and increase the efficiency of treatment equipment are proposed.

Introduction

The air basin is one of the most important resources of nature. Atmospheric air pollution is caused by changes in its composition and properties. It produces physical, chemical and biological agents that can have a negative impact on public health, the environment and more.

Atmospheric air pollution is the most important issue for scientists, because today pollution in cities and industrial regions is at a high level. Dangerous amounts of pollutants in the air pose a significant risk to the general condition of the human body.

Analysis of the literature. Many scientists in our country in recent years have devoted their work to studying the impact of industrial facilities on urban areas and human health, improving their environmental friendliness (M.O. Klimenko, A.M. Pryshchepa, O.A. Brezhitskaya, N.V. Merezhkina, V.V. Tarasova, M.V. Semenenko, V.G. Petruk [1-6].

According to research conducted in different periods, the relationship between the levels of air pollution due to emissions from thermal power facilities and the health of the population, in particular K.A. Bashtueva, V.F. Babiy, V.V. Zhdanov, S. Penney et al., B.O. Revich, I.O. Chernichenko and O.M. Litvichenko, M. Holland, C.K. Lin et al., 2019 [7-16].

Topicality. With the beginning of the industrial revolution, the amount of waste increased, the amount of discharges into water bodies and emissions of pollutants into the atmosphere increased significantly. Over time, it gained a planetary scale, which attracted the attention of mankind. The issue of global warming and climate change, global pollution and pollution of all areas of the environment. Therefore, assessing the extent of air pollution in cities and regions is a pressing issue today.

The aim of the work is to establish the scale and chemical composition of air pollution by industrial facilities on the example of Kyiv region; development of environmental measures to minimize the negative anthropogenic impact on the environment.

Research results

According to scientific research, regional reports of the Department of Ecology and Natural Resources, we can conclude that the state of the air in Kyiv region is quite tense. In 2017-2019, the quality of the air basin changed, but not significantly. An increase in the concentration of several pollutants and carcinogenic impurities, such as benzopyrene, was noted.

As Kyiv is the capital of Ukraine and Kyiv region is one of the largest in the country, environmental problems arise due to the large number of enterprises and vehicles in particular. Thermal power plants and the Chernobyl nuclear power plant play a particularly significant role here.

The key polluters of Kyiv region are enterprises of ferrous metallurgy (about 34%), energy (approximately 29%) and production of chemistry and petrochemistry (37%), as shown in Figure 1.

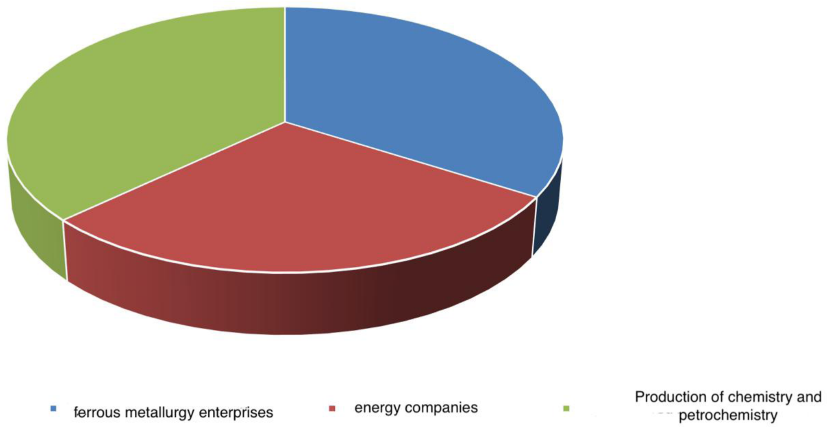

Fig. 1. The main polluters of Kyiv region as of 2019

Also, in the air note the content of 39 pollutants, including heavy metals. The most common are dust, carbon monoxide, nitrogen dioxide and sulfur.

Among the key polluting enterprises are the chemical industry, as hazardous emissions include sulfur dioxide, hydrogen sulfide, chlorine, fluorine and its compounds, nitrogen oxides and more. During chemical reactions, these substances are able to form high concentrations of toxic compounds.

The sources of air pollution are mobile and stationary sources. There are several cross-border connections in the Kyiv region, so a large amount of transport passes through routes, reservoirs and air. Road, river, air and railway vehicles have a negative impact due to emissions of pollutants into the air, because in the territory of Kyiv region all vehicles are found in particularly large quantities. That is why the amount of oxygen in the atmosphere decreases and the amount of harmful components of exhaust gases increases, in particular hydrocarbons, aldehydes, carbon monoxide, sulfur dioxide. In particular, gasoline engines emit compounds of lead, bromine, carcinogens; diesel – a significant amount of soot.

Stationary sources of air pollution play an equally important role. Stationary sources are objects that do not change their coordinates in space over time. These can be various productions, factories, shops, etc.

In 2017, more than 50,000 tons of pollutants entered the atmosphere of Kyiv region from stationary sources of pollution. Basically, a significant share falls on energy companies. However, it should be noted that in 2016 there were twice as many emissions from stationary sources. Based on the data of the Main Statistical Office in Kyiv region, the table of pollutant emissions from stationary sources in Kyiv region in 2020 by categories of pollutants is given.

From Table 1 we see that most of the stationary sources in 2020 were emitted sulfur dioxide, as well as a significant amount of particulate matter and nitrogen dioxide.

The analysis of air pollution indicators takes into account the amount of emissions of harmful substances from stationary and mobile sources of pollution. Atmospheric pollution has a negative impact on public health and the environment.

Table 1. Emissions of pollutants from stationary sources in Kyiv region by 2020, tons

	Amount of pollutants emitted into the atmosphere							
	sulfur dioxide	nitrogen dioxide	carbon monoxide	non-methane volatile organic compounds	polyaromatic hydro-carbons	solid particles 2,5	solid particles 10	ammonia
Total	27,017.7	6,495.1	2,669.9	1,566.8	27.6	15,169.0	1,388.4	785.4
Energy	26,560.1	5,164.5	1,314.9	137.7	0.0	13,661.9	162.4	15.3
Production	407.4	1,085.2	605.3	1,154.3	27.5	616.1	402.1	42.0
Agriculture	11.9	36.6	70.5	50.2	–	778.0	327.0	521.4
Waste	10.1	39.8	477.1	129.4	–	0.0	0.7	152.2
Others	28.2	169.0	202.1	95.2	0.1	113.0	496.2	54.5

The key air pollutants in Kyiv region include electrical and thermal equipment, industrial enterprises, agriculture and transport. One of the most important reasons for this state of the air basin of the region is the poor supply of these sources of emissions by dust collection equipment, installations for the capture of gaseous compounds of sulfur dioxide and nitrogen, volatile organic compounds and others.

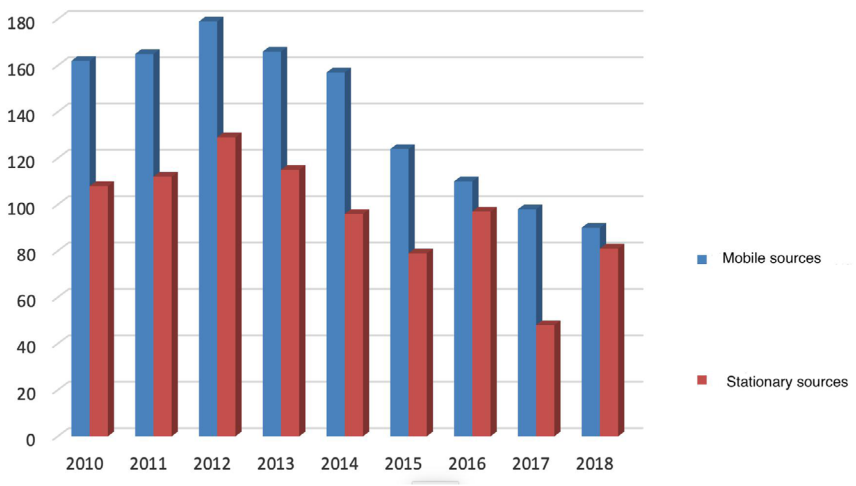

Fig. 2. Dynamics of pollutant emissions from mobile and stationary sources of Kyiv region in 2010-2018

Figure 2 shows the dynamics of emissions from mobile and stationary sources of pollution in the period from 2010 to 2018.

According to the schedule, there is a significant gap in the number of thousands of tons of pollutants between mobile and stationary sources. There has also been a reduction in emissions from the sources presented over 8 years.

Reductions in emissions from mobile sources can also be seen in this chart. In the period from 2013-2014 there is a significant decline in pollution from transport, as it was in this period was the beginning of the popularization of electric cars; transport with new, more equipped cleaning technologies, engines; the transition of the population to other modes of transport that do not harm the atmosphere – bicycles, scooters, etc.

Given the purpose of this study, we analyse the structural dynamics of emissions of pollutants in the Kyiv region according to the Main Department of Statistics of the Kyiv region.

As of 2019, there was an increase in emissions of pollutants into the air, in contrast to 2018. Such changes were observed both from mobile sources of pollution – 130.4 thousand tons, and from stationary sources, which amounted to 84.5 thousand tons.

Of the emissions from stationary sources, most emissions of dioxide and other sulfur compounds and substances in the form of solid suspended particles were observed. The air basin received almost 5 million tons of carbon dioxide.

Carbon dioxide CO_2 is a colourless gas that irritates the respiratory tract, causing dizziness, headaches and other ailments in humans. Also, in large quantities adversely affects the state of the atmosphere.

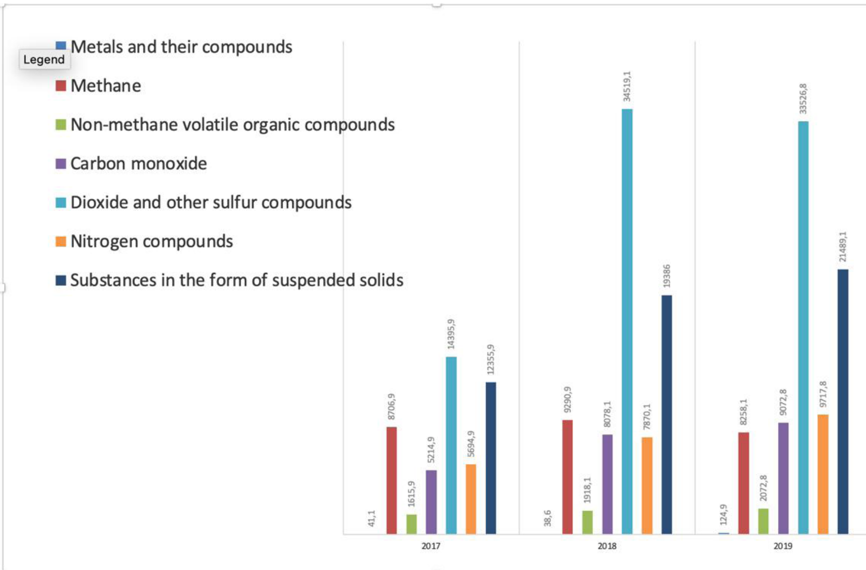

Fig. 3. Emissions of major pollutants into the atmosphere in the period from 2017 to 2019 from stationary sources of pollution in the Kyiv region, thousand tons

Based on the data of the Regional Report "On the state of the environment of Kyiv region in 2019" we can analyse the data on emissions of carbon dioxide and other major substances that pollute the atmosphere (Fig. 3).

According to Figure 3, we can conclude that in the period from 2017 to 2019, the amount of major pollutants in the air from stationary sources of pollution has increased significantly. If 2018-2019 have approximately similar values, except for the amount of emissions of persistent organic pollutants and polyaromatic hydrocarbons, then separately for 2017 and 2019 there is an increase in emissions of major pollutants almost twice.

Based on the data of the Main Department of Statistics in Kyiv region, diagrams of the amount of pollutant emissions by cities and districts of Kyiv region as of 2020 are shown (Figs. 4, 5).

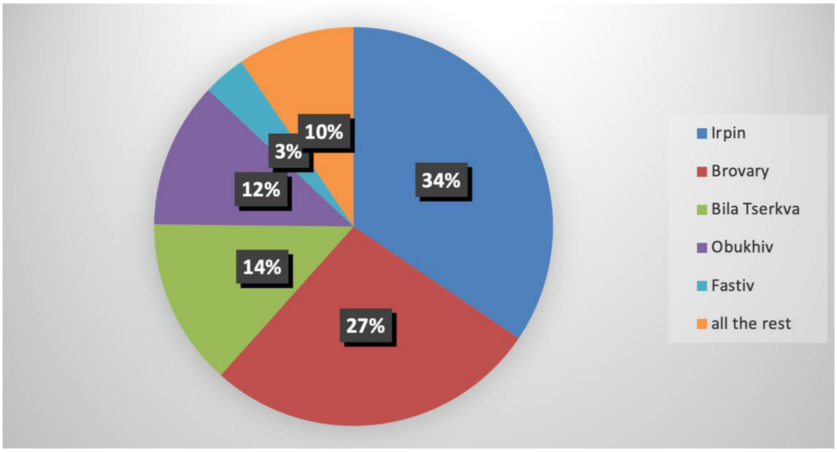

Fig. 4. The most polluted cities of Kyiv region

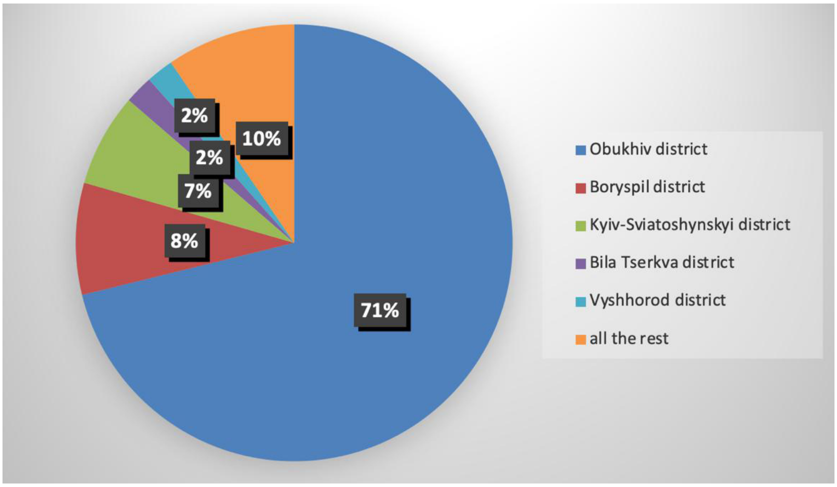

Fig. 5. The most polluted areas of Kyiv region

According to Figures 4 and 5, the most polluted cities of district significance of Kyiv region include the city of Irpin, Brovary, Bila Tserkva, Obukhiv and Fastiv. Leads the list of Irpin with 1219.8 tons of emissions.

The most polluted districts of the region are: Obukhiv, Boryspil, Kyiv-Sviatoshynskyi, Bila Tserkva and Vyshhorod districts. The list is headed by Obukhiv district with 44,842.4 tons of emissions.

The main reason for the pollution of these cities and districts is the high level of man-made load and the number of enterprises that emit into the atmosphere. Within the Kyiv region there is an uneven location of enterprises, which, in turn, exacerbates the negative state of the air in Kyiv region.

In the Kyiv region, most of the pollution is accounted for by mobile energy sources, as there are several cross-border transport corridors in the region, which means a large number of all modes of transport in this area. Emissions from stationary sources are at the second place, but their share is no less significant, as hundreds of enterprises and various industries are concentrated in the region, which also contribute to emissions into the atmosphere. The key polluters are energy companies, as they account for more than 80% of all pollution.

Figures 6 and 7 show the enterprises that cause the greatest damage to the air of Kyiv region in terms of total emissions of pollutants and carbon dioxide emissions in 2018. From stationary sources the biggest polluters are Trypillya TPP, Agromars Complex, Bila Tserkva CHP, Yagotynske LVUMG, 35 Compressor Station, PJSC Vetropack Gostomel Glass Plant, etc.

The main causes of air pollution by these enterprises are the use of outdated technologies, most of which do not meet modern environmental requirements, as well as the low level of operation of dust collection equipment.

According to Figures 6 and 7, it can be concluded that the greatest damage to the air of Kyiv region is caused by Trypillya TPP. Bila Tserkva CHP also showed a significant indicator of carbon dioxide emissions.

Thus, Trypillia TPP is the largest stationary source of pollution in Kyiv region.

Trypillia Thermal Power Plant is the most powerful station in the Kyiv region and, at the same time, the biggest polluter, as it operates on coal. As of 2016, more than 55,000 tons of pollutants were released into the atmosphere from this station, which is part of the entire region. After the shutdown of the Chernobyl nuclear power plant, the Trypillia station took the place of the largest energy generating enterprise.

Kyiv region is considered to be one of the most energy-intensive areas. Here are energy generating enterprises with a total capacity of over 3 thousand MW, of which the installed capacity of Trypillia TPP is about 56%. That is why this company is the most important supplier of electricity in several regions: Kyiv, Zhytomyr and Cherkasy. The station, with an area of 280 hectares, is located in the Obukhiv district near the Kaniv Reservoir. That is why the city of Obukhiv and the whole Obukhiv region is the only territory in which emissions from stationary sources predominate, and not from mobile ones. The power plant is located more than 40 km from the region, near the historic settlement of Trypillya, whence it got its name.

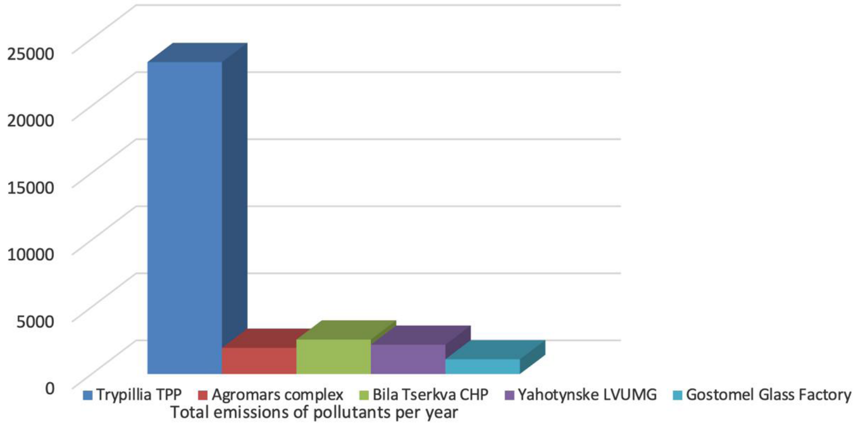

Fig. 6. Emissions of pollutants from the main sources of pollution in Kyiv region in 2018

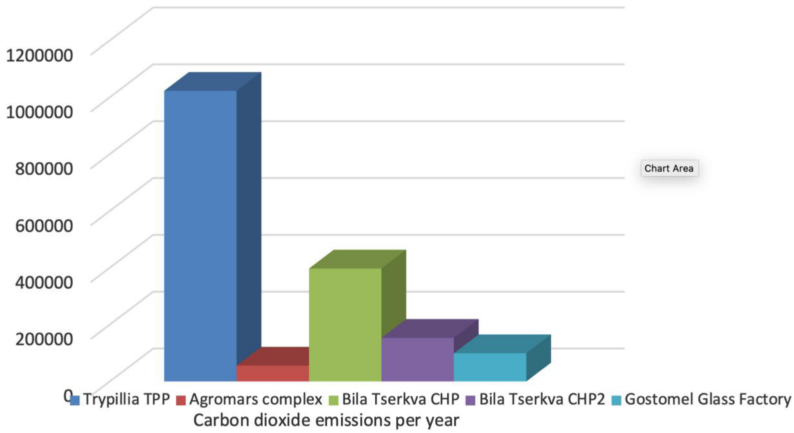

Fig. 7. Carbon dioxide emissions from the main sources of pollution in Kyiv region in 2018

From the beginning of construction, this TPP had 4 power units, each of which had a capacity of 300 MW. Subsequently, 2 more identical blocks were completed. Thus, it has 6 main power units – 4 pulverized coal and 2 gas and oil units. Also contains six turbines and power converters-generators with a capacity of 1800 MW.

The main fuel is anthracite, which contains more than 85% carbon and enters the station berth by rail and river. The station belongs to the Ukrainian gas transport system, so the fuel industry has the capacity to use fuel oil as fuel. Reserve fuel – gas.

Since the start of operation of Trypillya TPP, more than 360 billion kW of electricity and 5.7 million Gcal of heat have been generated.

It is the thermal energy companies that cause the most damage to the environment caused by the combustion of fossil fuels. TPPs not only pollute the atmosphere with nitrogen and sulfur compounds, they contain very toxic impurities – beryllium, cadmium, mercury, etc., which are released into the air in the form of gaseous, solid and aerosol compounds. In any form, such impurities adversely affect the human body and other living organisms.

During the combustion of fuel oil, sulfur oxide, nitrogen, and aromatic hydrocarbons enter the air. During the combustion of natural gas – nitrogen oxides, but in much smaller quantities.

Based on the data of environmental passports of Kyiv region in the period from 2017 to 2019, Figures 8 and 9 are shown, which show the dynamics of emissions of major pollutants from Trypillia TPP during 2017-2019. These are mainly metals and their compounds, substances in the form of suspended solids, nitrogen compounds, dioxide and other sulfur compounds, carbon monoxide and methane.

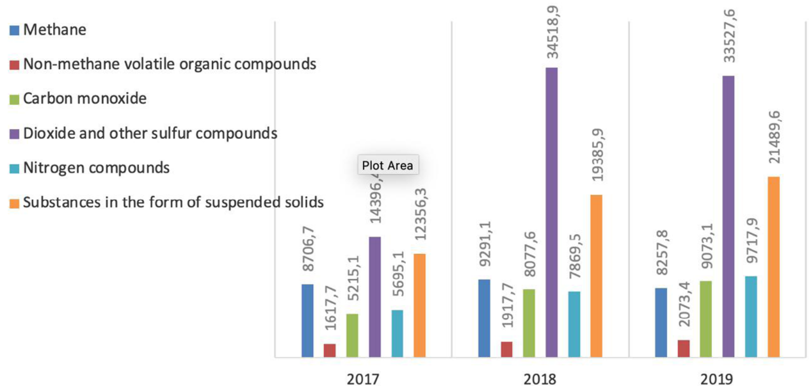

Fig. 8. Dynamics of emissions of the main pollutants of Trypillya TPP in 2017-2019, thousand tons

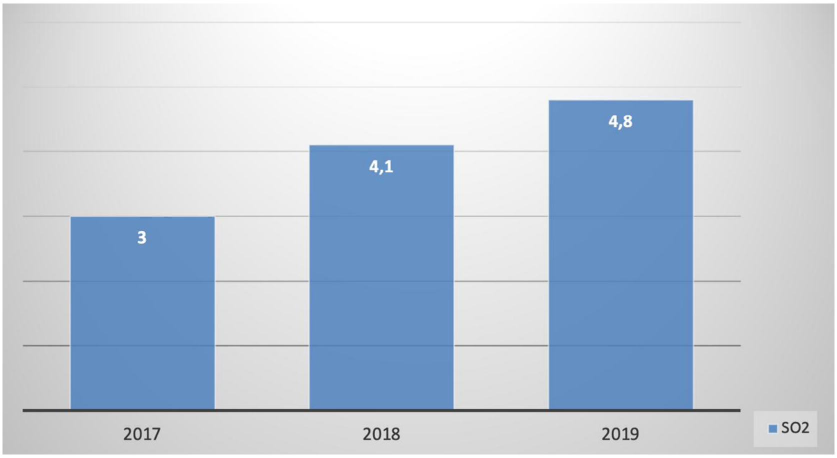

Fig. 9. Dynamics of SO_2 emissions from Trypillia TPP in 2017-2019, million tons

Emissions of sulfur dioxide have almost doubled in three years, and emissions of carbon monoxide, suspended solids and nitrogen compounds have almost doubled. This is due to unsatisfactory and low-efficiency operation of treatment equipment and increased intensity of operation of the thermal power plant.

Discussion of results. Thermal power plant – a complex system for fuel production, which is formed from many equipment, each of which undergoes certain processes. The station consists of fuel economy and preparation of this fuel for combustion (fuel can be fuel oil or natural gas), boiler equipment (boiler and auxiliary installations), equipment for preparation of water supply and condensate treatment, technical water supply and ash removal systems, electronic equipment and their management systems.

The operation of thermal power plants has a negative impact on the environment and human in particular. With the use of solid fuels from thermal power plants, parts of the ash that are not captured by gas treatment plants, unburned fuel residues, sulfur dioxide, nitrogen and carbon oxides are released into the atmosphere. And the use of natural gas releases toxic oxides of nitrogen, carbon and benzopyrene.

All significant changes due to the operation of thermal power plants are due to the use of low-grade fuel, outdated production technologies and outdated equipment, low-efficiency facilities for cleaning and filtering emissions, lack of environmental protection systems, lack of incentives for environmentally friendly technologies and lack of environmental control.

Trypillya TPP needs reconstruction of the equipment, after which its efficiency indicators will be more reliable and safer, the term of use of the units will be extended. Considerable attention is paid to this issue, as the station is located in the most visited area. The electrostatic precipitator in the first power unit was reconstructed at the station, the efficiency of which is currently 99%. In order to reduce the concentration of sulfur oxides in the flue gases, it is planned to install a sulfur treatment plant, which will remove dust in bag filters.

In order to speed up the way to reduce emissions from fuel combustion, it is necessary to replace solid fuel with gas (there are also emissions from gas, but in much smaller quantities), improve the quality of fuel, properly dispose of waste, install more modern gas and dust. treatment plants (which will allow production to move more efficiently), introduce renewable energy sources where possible.

Conclusions

With the beginning of the industrial revolution and technological progress, the number of different industries has increased significantly, providing a more stable economy, but less satisfactory state of the environment. Atmospheric air, as the main element of the biosphere, is also exposed to this influence. Thermal power plants and thermal power plants have the most negative impact on the environment.

That is why this issue is being considered at the legislative level, as it is important to focus efforts on preserving and restoring the natural state of the air basin, creating better living and working conditions, ensuring environmental safety and avoiding harmful effects on air health and the environment.

To prevent an environmental catastrophe that could be caused by significant emissions into the air basin, efforts should be made to minimize and prevent emissions through the use of environmental filters, the transition to environmentally friendly equipment, control of waste management (including incineration). Attention should also be paid to the implementation of environmental measures.

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Sustainable development – state and prospects (SDEV'2022)
Mirosław Borkowski, Oleksandr Moroz, Mykhailo Paslavskyi (red.)
Wydawnictwo GSW • Gdańsk 2023 • ISBN 978-83-66270-30-5

UDC 338.48 (477)

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Trends in the development of heroic-patriotic tourism in the Carpathian region of Ukraine

Abstract
In the current conditions of the war in Ukraine, when the country defends freedom and territorial integrity at the cost of life and efforts of the Ukrainian military, volunteers, volunteers, national and patriotic importance becomes a priority. Given this, it is important to assess the tourism potential for the development of heroic and patriotic tourism in Ukraine. In this article we analyzed the development trends of heroic and patriotic tourism on the example of the Carpathian region (which includes four regions of Western Ukraine: Lviv, Ivano-Frankivsk, Transcarpathian, and Chernivtsi), which on the tourist map of Ukraine is gradually becoming an attractive tourist and recreational region. has great prospects for development. Lviv region belongs to the regions of Ukraine where there are the most favorable opportunities for the development of heroic and patriotic tourism. The region has a significant number of heroic and patriotic resources, in total, more than 170. Among all types of heroic and patriotic resources, the largest share is occupied by monuments and memorial sites associated with prominent figures of the national liberation struggle, burials are on the second places, monuments and memorials associated with significant historical events and their participants occupy the third position, museums and museum exhibits occupy the fourth position and military infrastructure (hiding places) in number are in fourth place. Transcarpathia, given the historical peculiarities of its formation, also has significant resources for the development of heroic and patriotic tourism. The treasury of cultural heritage of the Transcarpathian region includes monuments of archeology, history, architecture, and monumental art. In addition, scientific, cognitive, cultural heritage plays an important role in the national-patriotic education of youth, clearly showing the identity of the culture of the Ukrainian people, the continuity of the present with the past. Ivano-Frankivsk region, one of the regions of Ukraine, where the national liberation movement in the 1940s and 1950s was the largest in the country, therefore, the region has a large number of material and spiritual monuments, including museums. The region is actively developing tourist routes to places associated with the liberation movement in the last century. According to research, about 170 objects of heroic and patriotic tourism have been identified in the region. Chernivtsi region also has a large number of museums and memorial sites associated with the life and work of prominent figures of science and culture of Bukovina and Europe, belonging to various national cultures, including Ukrainian, Romanian, Jewish, German, and others. Burials are important among the heroic and patriotic resources of Bukovina. Interesting heroic and educational resources of the Chernivtsi region are memorial museums that have a high level of cognitive value and are the basis for the formation of sightseeing and tourist routes in this area. In total, more than 600 tourist sites have been discovered in the region, among which the most numerous are burials and monuments and memorial sites associated with significant historical events and their participants. In particular, museums and military infrastructure are of great interest to tourists, the largest number of them were found in Lviv and Ivano-Frankivsk regions. Unfortunately, some of the analyzed resources are partially, and sometimes destroyed, due to the military actions of the Russian Federation throughout Ukraine! In such conditions, patriotic upbringing of young people is especially important, which promotes the formation of patriotism, love for their people, their history, cultural and historical values, an important component of which, after the war, should be the organization of tourist trips involving heroic and patriotic resources of the country's regions.

Introduction

In the current conditions of the war in eastern Ukraine, started by Russian troops who invaded the Ukrainian Donbas in April 2014 and after the Russian occupation of Crimea, the war lasted 8 years in a "hybrid" state until February 24, 2022, a large-scale invasion of the Russian army to Ukraine along the entire length of the common border and from the territory of Belarus.

In such conditions, patriotic upbringing of young people is especially important, which promotes the formation of patriotism, love for their people, their history, cultural and historical values, an important component of which, after the war, should be the organization of tourist trips involving heroic and patriotic resources of the country's regions.

Analysis of the literature

Heroic and patriotic tourism is a fairly new type of tourism, which covers a number of concepts, in particular, military-historical, military-patriotic, patriotic, etc. These types of tourism were distinguished by such scientists as M. Klyap, F. Shandor, I. Golyboroda, and others. Modern research of heroic and patriotic tourism is associated with the works of Kadnichansky D., Karas G., Scutar T., Kuchinskaya I., Dorosh Y., Anipko N., and others. In particular, in the work of Kuchynska I., Dorosh Y. Heroic and patriotic tourism as a promising direction of tourism development in Galicia in modern conditions, the authors propose to use the term "heroic and patriotic tourism" as a kind of cultural and cognitive (namely, historical) tourism, which includes travel to their own country, in order to divert attractions and memorable places related to the history of the national liberation struggle, heroic events and figures of the past. And aimed at increasing the sense of patriotism. In essence, this type of tourism is aimed primarily at „domestic tourists" [4]. We analyzed the main types of resources used in the organization of heroic and patriotic tours in the Carpathian region of Ukraine and their importance for the patriotic education of youth.

Topicality

In the current conditions of war in Ukraine, when the country at the cost of life and efforts of Ukrainian soldiers, volunteers, volunteers defends freedom and territorial integrity, the priority is national-patriotic and military-patriotic education of youth, raising national awareness and knowledge of the history of national liberation people. Given this, the assessment of the tourist potential for the development of heroic and patriotic tourism in Ukraine, which we studied on the example of the Carpathian region, is especially relevant.

Research results

Therefore, consider the development of heroic and patriotic tourism in the example of the **Carpathian region** (which includes four regions of Western Ukraine:

Lviv, Ivano-Frankivsk, Transcarpathia, and Chernivtsi), which on the tourist map of Ukraine is gradually becoming an attractive tourist and recreational region. great prospects for development. **Lviv region** belongs to the regions of Ukraine where there are the most favorable opportunities for the development of heroic and patriotic tourism. This is primarily due to the long struggle for freedom, independence, and autonomy of Ukraine. There are settlements in the region with a significant number of heroic and patriotic resources, in total, more than 170. Among all types of heroic and patriotic resources, the largest share is occupied by monuments and memorial sites associated with prominent figures of the national liberation struggle – more than 30% of the total structure. The most famous of this category are the monuments to S. Bandera in various settlements, monuments to R. Shukhevych (Belogorshcha, Krakovets), E. Konovalets (Zashkiv, Zhovkva), J. Stetska (Stryj), V. Kuku (Busk) and others. Burials are in second place, about 30% of the total structure. Among the most famous burials in the Lviv region are Lychakiv Cemetery, Memorial Cemetery in Makivka, Slavska Mlaka, and others.

Monuments and places of interest related to significant historical events and their participants occupy the third position – more than 15% of the total. Museums and museum expositions occupy the fourth position – more than 10%. In our opinion, these are the most valuable resources of heroic and patriotic tourism, because, in fact, the museum exhibits a significant number of objects collected in one place. In the Lviv region, one of the most famous museums is, of course, the memorial museums of the three leaders of the UPA, namely: the Historical and Memorial Museum of Yevhen Konovalets in the village. Zashkiv, Museum of General-Cornet of the Ukrainian Insurgent Army Roman Shukhevych in the village of Belogorsk and the Stepan Bandera Museum in Dubliany. Military infrastructure facilities (hideouts) are in fourth place in number – about 10% of the total structure. In particular, it is a hiding place-museum in the village. Basivka, a museum-hideout of UPA soldiers in the village of Gavarechchyna, hide-and-seek museum in the village of Sprynya, and others. In the current conditions of Ukraine's formation and the further struggle for a united and united state, new monuments related to the Heroes of the Maidan and soldiers who died in the anti-terrorist operation have emerged: in particular, the burial of the Heroes of the Heavenly Hundred. Heavenly Hundred inspired hundreds of thousands of Ukrainians to fight against Russian aggression, and today brave soldiers give their lives every day for our peaceful life in Ukraine [4].

The next region of the Carpathian region, which we studied – **Transcarpathian**, given the historical features of the formation, also has significant resources for the development of heroic and patriotic tourism. The treasury of cultural heritage of the Transcarpathian region includes monuments of archeology, history, architecture, and monumental art. In addition, scientific, cognitive, cultural heritage plays an important role in the national-patriotic education of youth, clearly showing the identity of the culture of the Ukrainian people, the continuity of the present with the past. Let's take a closer look at some of them. Monument to Roman Shukhevych. In 2012, a bust of Roman Shukhevych was installed on the territory of the museum – open-air museum

"Old Village", on the eve of the 70th anniversary of the Ukrainian Insurgent Army and the Day of the Ukrainian Cossacks. The monument was erected next to the Carpathian Ukraine exposition. It became part of the tourist route, which reproduces the national liberation movement in Transcarpathia and Kolochava. In 2018, a monument to the victims of the Holodomor was erected in Uzhhorod. The same year in Uzhgorod on the Hill of Fame was the consecration of the Memorial to the fallen soldiers of the ATO. This memorial is a testament to the fact that Transcarpathians will always remember those who gave their lives defending Ukraine from Russian aggression. And Veretsky Pass, famous for centuries, connects the Ukrainian Carpathians, Transcarpathia, and Lviv region – through the picturesque watershed. During the Second World War, in the spring of 1939, Hungarian fascists brutally shot about 500 soldiers and volunteers of the Carpathian Sich, an organization that defended and defended the independence of Carpathian Ukraine. Now there are many mass graves. This is one of the most painful pages in the history of Ukraine [2].

Ivano-Frankivsk region, one of the regions of Ukraine, where the national liberation movement in the 1940s and 1950s was the largest in the country, therefore, the region has a large number of material and spiritual monuments, including museums. The region is actively developing tourist routes to places associated with the liberation movement in the last century. According to research, about 170 objects of heroic and patriotic tourism have been found in the region, most of which are burials – about 40%, both single and mass graves. In second place are monuments and memorial sites associated with prominent figures of the national liberation struggle – more than 20%. In addition, the region has a significant number of memorials and memorial plaques dedicated to famous figures of the national liberation struggle. As well as monuments to Stepan Bandera, Roman Shukhevych, Dmytro Vitovsky, Yaroslav Melnyk, Yaroslav Stetsko and others. The third position is occupied by monuments and memorial sites associated with prominent historical poems and their participants – more than 15%, among them – memorials in battlefields, symbolic monuments to "Fighters for the Freedom of Ukraine", a monument to the proclamation of Western Ukraine in Stanislavov, etc. The fourth place is occupied by museums and museum expositions – less than 15%, although their number is quite large. These are memorial museums, museums of the national liberation struggle, and separate expositions in museums of historical profile. And the last position is occupied by hideouts – up to 10% [4]. Several monuments have been erected in modern Ivano-Frankivsk – mostly to Ukrainian national figures of culture and history – Ivan Franko, Stepan Bandera, Vasyl Stefanyk, etc. The city with a rich Christian tradition also has religious monuments – statues of the Blessed Virgin Mary and Jesus Christ. During the period of independence (since 1991), almost all examples of Soviet monumental propaganda were removed in the city, except for the stele in honor of the 40th anniversary of the liberation of the city from German troops in World War II. whose name is the city. Several monuments in Ivano-Frankivsk are dedicated to the brightest events of national history, in particular the monument in honor of the proclamation of the capital of the Western Ukrainian People's Republic in Stanislaviv (2004). And on December 31, 2013, in Ivano-Frankivsk, the world's first monument to the "Russian Trinity" was erected. On May 23, 2019, a monument to Roman Shukhevych was erected in Ivano-Frankivsk. An important place among the heroic and educational tourist resources of the Ivano-Frankivsk region is occupied by the Historical and Memorial Museum of Oleksa Dovbush, opened in September 1995, and in 1997 the museum received state status; Stepan Bandera Regional Museum of the Liberation Struggle and the Demyaniv Laz Memorial Complex (Branch of the Stepan Bandera Regional Museum of the Liberation Struggle); Ivano-Frankivsk Museum of Liberation Struggle of the Carpathian Region and the Museum of the Liberation Struggle in Kosovo [5].

Chernivtsi region also has a large number of museums and memorial sites associated with the life and work of prominent figures of science and culture of Bukovina and Europe, belonging to various national cultures, including Ukrainian, Russian, Romanian, Jewish, German, and others. The glorious names of Yuri Fedkovych, Olga Kobylyanska, Sidor Vorobkevych, Mykhailo and Volodymyr Ivasyuk, Ivan Mykolaychuk, Nazariy Yaremchuk, Augusta Kokhanovska, Mihai Eminescu, Paul Celan, George Drozdovsky and many others are connected with the Bukovyna region. M. Hrushevsky, Lesya Ukrainka, M. Kotsyubynsky, I. Franko, V. Stefanyk, M. Lysenko, S. Krushelnytska, F. Liszt, E. Caruso, and others visited here. In total, there are 195 sites belonging to the biosocial recreational and tourist resources, including 4 – of national importance. Among them are 24 memorial museums, of which 6 states [6]. There are many monuments in the city of Chernivtsi, both to Ukrainian figures of history and culture, and dedicated to the years of World War II and the national liberation struggle. Burials are important among the heroic and patriotic resources of Bukovina. A significant number of military burials appeared in Chernivtsi and its environs during the First World War. At this time, military burials also appeared in the Jewish cemetery, which was built in October 1923 as the "Cemetery of Heroes". The Victory Obelisk was erected in 1946 to commemorate the first anniversary of the victory over Nazi Germany. On the site of an unfinished Romanian military monument to an unknown soldier. Along with honoring the memory of fallen soldiers in the 50s of the twentieth century. honored the memory of the underground. With the creation of independent Ukraine, the emphasis on views on certain events of World War II has changed. Due to this, in Chernivtsi, there was an opportunity to erect a monument to soldiers and participants of the Bukovynian smokehouse (1918, 1941, 1944) on September 24, 1995, with the participation of residents and veterans of the smokehouse and its commander P. Voinovsky [3]. Among the monuments that symbolize the modern era in Chernivtsi, for example, on the street Heroes of the Heavenly Hundred in November 2019 consecrated a memorial stone, it is on the site of this sign-stone November 30, 2021, opened the Memorial to the Heroes of the Heavenly Hundred, in on this day, eight years ago, peaceful student protesters were beaten on the Maidan. Interesting heroic and educational resources of the Chernivtsi region are memorial museums that have a high level of cognitive value and are the basis for the formation of sightseeing and tourist routes in this area. There are a total of 24 memorial museums in the region, most of which are located in the Vyzhnytskyi district (7) and Chernivtsi (6). In particular: Volodymyr Ivasyuk Memorial Museum, Chernivtsi Literary Memorial Museum of Yu. Fedkovych, Ethnographic Museum named after Yu. Fedkovych, Chernivtsi Literary Memorial Museum of O. Kobylyanska and others.

Medieval castles and fortresses are also popular places of heroic and educational tourism in the world and Ukraine. The most popular among the animation events, which present military-historical themes, are the festivals of military-historical reconstruction, military-historical and medieval culture. Examples of such festivals in Bukovyna are the International Festival of Historical Reconstruction of the Middle Ages "Battle of Nations", the International Military History Festival "Khotyn Fortress", International Historical Festival "Medieval Khotyn" [1].

Conclusions

Thus, the Carpathian region has significant resource potential for the development of this type of tourism and has a unique historical and cultural heritage, in particular: "Ancient Halych" National Historical and Cultural Reserve, "Khotyn Fortress" State Historical and Architectural Reserve, Museum-Reserve Zolochiv Castle, Lychakiv Cemetery Historical and Cultural Reserve, Olesky Castle State Museum-Reserve and many others, Main tourist centers: Lviv, Ivano-Frankivsk, Uzhhorod, Chernivtsi. In total, more than 600 tourist sites have been discovered in the region, the most numerous of which are burials and monuments, and memorial sites associated with significant historical events and their participants. In particular, museums and military infrastructure, including hideouts, are of great interest to tourists. The largest number of them was found in Lviv and Ivano-Frankivsk oblasts, however, a significant part of the resources is not fully used for the development of heroic and patriotic tourism in the region. Unfortunately, some of the analyzed resources are partially, and sometimes destroyed, due to the military actions of the Russian Federation throughout Ukraine! In such conditions, patriotic upbringing of young people is especially important, which promotes the formation of patriotism, love for their people, their history, cultural and historical values, an important component of which, after the war, should be the organization of tourist trips involving heroic and patriotic resources of the country's regions.

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