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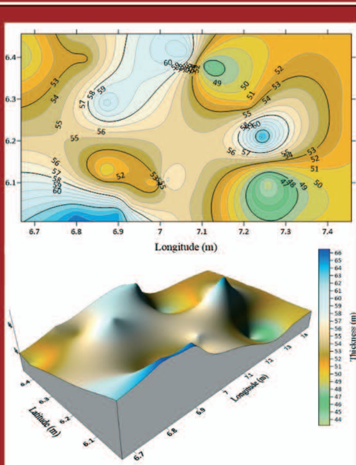
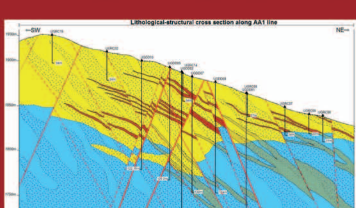


Geo-electric Techniques

Geology of the Rybalsky Quarry



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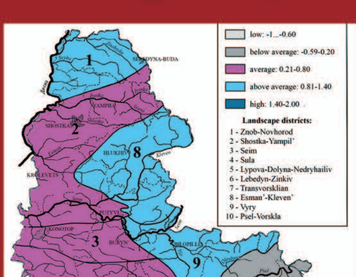

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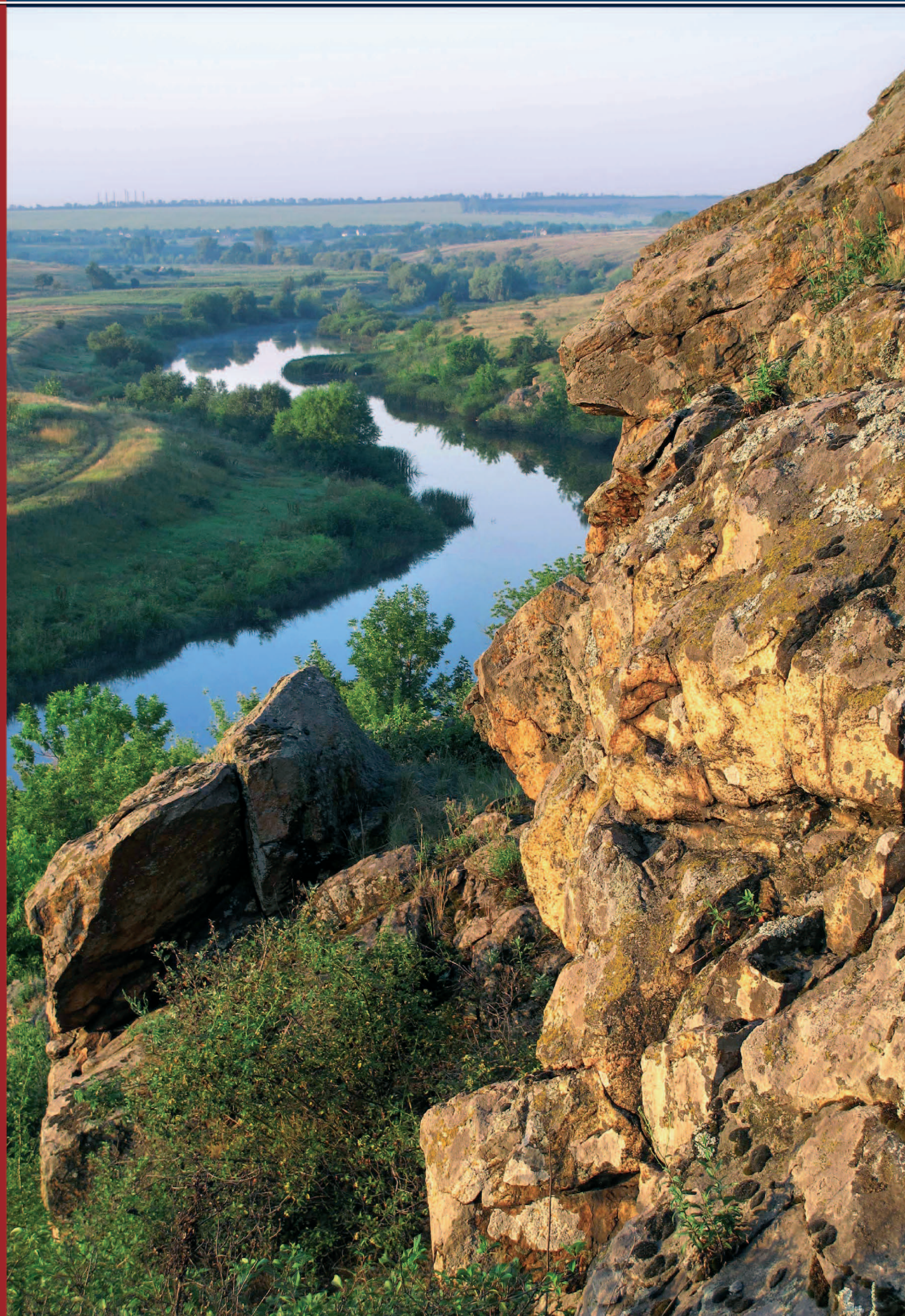

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Impact of economic activity on geoecological transformation of the basin of the Zhovtenka River (Ukraine)

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Abstract. The article presents the results of the study on the current geoecological condition of the basin of the Zhovtenka River. The study object corresponded to the criteria of a small river, having the length of 42 km and the area of the drainage basin of 293 km^2. According to the geographic peculiarities and the level of anthropogenic impact it is a typical small river of the Ukrainian Steppe zone. At the current stage of water management, the river and its tributaries are significantly regulated by artificial aquatic objects – ponds and a water reservoir. The total number of hydrotechnical facilities that form the water bodies is 34 levees. On the river itself, average density of water bodies equals 1 pond per every 2 km of the river length. Such regulation contradicts the norms of the current water protection legislation of Ukraine. As a result of fragmentation, the river has turned into a cascade of evaporation ponds. Special ecological threat to water use is the quality of water in the ponds. We determined that due to absence of current and low water exchange, the saline content in water undergoes significant changes. During the field surveys, we collected samples and determined the parameters of mineralization, content of chlorides and sulfates in 10 water bodies. Sampling was carried out during the year in different seasons. We determined that the averaged parameters of mineralization level change within the range of 9.000 mg/dm^3 in spring to 13.000 mg/dm^3 in summer and autumn. The content of chlorides varies within 2.600-3.600 mg/dm^3, sulfates – 4.000-4.800 mg/dm^3 according to the similar seasonal dependence. Due to changes in the climatic conditions and current tendencies of warming and dry climate, decrease in the water resources heightens the risks of irreversible geoecological degradation of the river. Significant regulation and evaporation-caused loss of water leads to rapid shoaling of the water bodies and growth of aquatic-marsh vegetation. The authors suggest an approach to assessment of the level of geoecological transformation of the river basin based on determining quantitative parameters of the constituents of the elements of natural ecosystems and elements of negative anthropogenic impact. We proposed calculation of various coefficients (indicators) which alter the natural condition of water ecosystems, particularly: coefficients of fragmentation, coefficients of urbanization, coefficients of alienation, etc. We present a possibility of using them in relation to the length of the river and hydrographic network, as well as the area of drainage. We determined that percentage parameter of geoecological impact was seen in 94.3% of the area of the drainage basin or 87.4% of the river length. We suggest approaches that would minimize the deleterious impact of economic activity and gradually restore the condition of aquatic ecosystem of the river. The article provides recommendations of using coefficients of geoecological transformation of river ecosystems.

Key words: river basin, geoecological transformation, ecological safety, artificial water bodies

Вплив господарської діяльності на геоекологічну трансформацію басейну річки Жовтенька (Україна)

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Анотація. У статті представлено результати дослідження сучасного геоекологічного стану басейну річки Жовтенька. Об'єкт досліджень відповідає критеріям малої річки з довжиною 42 км та площею водозбірного басейну 293 $км^2$. За географічними особливостями та рівнем антропогенного впливу є типовою малою річкою степової зони України. На сучасному етапі водогосподарської діяльності, річка та її притоки значно зарегульовані штучними водними об'єктами – ставками і водосховищем. Загальна кількість гідротехнічних споруд, що формують водойми, складає 34 греблі. Безпосередньо на річці середня щільність розташування водойм складає 1 ставок на кожні 2 км довжини річки. Таке зарегулювання суперечить нормам чинного водоохоронного законодавства України. Внаслідок фрагментації річка перетворилась на каскад ставківвипаровувачів. Особливу екологічну небезпеку водокористування становить якість води у ставках. Визначено, що через відсутності течії і низького водообміну значно змінюється сольовий склад води. В ході польових досліджень проведено відбір проб та визначені показники мінералізації, вмісту хлоридів і сульфатів у 10 водоймах. Відбір проб виконувався протягом року за різними сезонами. Встановлено, що усереднені показники рівня мінералізації змінюються в межах від 9000 мг/дм^3 навесні до 13000 мг/дм^3 влітку та восени. Вміст хлоридів коливається в межах 2600-3600 мг/дм^3, сульфатів 4000-4800 мг/дм^3 за аналогічною сезонною залежністю. У зв'язку зі зміною кліматичних умов та сучасних тенденцій потепління і посушливості клімату, зниження водності підвищує ризики безповоротної геоекологічної деградації річки. Значне зарегулювання та втрати води на випаровування призводять до стрімкого обміління водойм та заростання водно-болотяною рослинністю. Авторами запропоновано підхід щодо оцінювання рівня геоекологічної трансформації річкового басейну, який спирається на визначенні кількісних показників складових елементів природної екосистеми та елементів негативного антропогенного впливу. Запропоновано оцінювати різні коефіцієнти (показники), що змінюють природний стан водних екосистем, а саме: коефіцієнти фрагментації, коефіцієнти урбанізації, коефіцієнти відчужень тощо. Представлена можливість їх застосування як за довжиною річки та гідрографічної мережі, так і за площею водозбору. Встановлено, що відсотковий показник негативного геоекологічного впливу спостерігається на 94,3% площі водозбірного басейну або 87,4% за довжиною річки. Запропоновано підходи, що дозволять мінімізувати негативний вплив господарської діяльності та поступово відновити стан водної екосистеми річки. Наведені рекомендації прикладного застосування коефіцієнтів геоекологічної трансформації річкових екосистем.

Ключові слова: басейн річки, геоекологічна трансформація, екологічна безпека, штучні водойми

Introduction.

Hydrotechnical construction has a history of around 5 thousand years. In all the continents (except Antarctica), millions of dams and flood-prevention levees have been constructed in small and large rivers, thus elevating hydroenergetics, water supply, transport, fish farming, recreation, and sport to a new level of development. Levees reduced the threat of floods and allowed people to settle and cultivate productive alluvial soils in the floodplains of rivers, and work on aquatic meliorations. The hydrotechnical construction peaked in the last 100 years.

Having considered the high importance of artificial water bodies for increase in available-to-use aquatic resources in farming (Hogeboom et all., 2018), we should note that non-systemic, often not correlated with the general plan, creation of water reservoirs and ponds on small rivers, which moreover is often performed at low engineer level, may have unfavourable economic and ecological consequences (Yatsyk et al., 1991).

At the same time it has to be noted that despite the great role of small rivers in the formation of natural environment and runoff of large watercourses (Lapsenkov, 1983), the study of their hydrological and hydrochemical regime is of episodic, non-systemic character. Often small rivers remain without monitoring, care, control and protection.

The increasing demand for restoration of ecological balance of complex technonatural ecosystems is currently leading scientists to pay attention to historical aspects of development and functioning of watercourses (Manyuk, 2017), and moreover the need for studying contemporary tendencies of geoecological transformation is becoming relevant. The performed studies focus on the hydrological characteristics of rivers of the steppe zone of Ukraine (Dovhanenko et all., 2017), hydrochemical parameters of quality of aquatic resources (Rudakov L. et all., 2020) and effect of chemical composition of atmospheric precipitations on their formation (Khilchevskyi et all., 2018, 2019). Largely, developing studies are those using modern geoinformational systems and technologies (Kulikova et all., 2018; Rebati et all., 2019; Shevchuk et all., 2019). In all the studies the authors try to directly or indirectly assess the ecological condition of aquatic ecosystems. Currently, there are scientific approaches to integral assessment of ecological stability of geosystems (Dmitriev et all., 2012, 2016) and their ecological balance (Reimers, 1990), which are mostly based on taking into account biotic (natural) components.

At the same time, much less attention is paid to study of construction and exploitation of hydrotechnical facilities as technical components of the elements of influence on aquatic objects (Yu-jun et all., 2019; Andrieiev V. et all., 2020). In particular, construction of levees provokes a number of negative effects related to transformation of hydrological, hydrobiological and sanitary regimes of rivers. After levees are exploited for a long period of time and also due to their incorrespondence with the norms of reliability and safety, there occur ecological risks of hydrodynamic emergencies (Hapich, 2019). Currently, non-systemic regulation of small and average rivers with numerous violations of the norms of current legislation (Vodnyi кodeks Ukrainy, 1995) has led to the creation of cascades of artificial water bodies and transformation of river ecosystems into aquatic-marshland areas.

Positive global experience and attitude to regulation of river runoff of small watercourses demonstrates the necessity of and tendency to dismantling of levees, restoration of the current and ecosystem of small rivers (Bednarek, 2001; Fuller et all., 2015; Magilligan et all., 2016)

The objective of our study was creating and substantiating a theoretical model of the effect of economic activity on geoecological transformation of basins of small rivers of the steppe zone of Ukraine on the example of the Zhovtneva River. Theoretical analysis of the literature sources (Reimers, 1990; Yatsyk et all., 1991; Dmitriev et all., 2012, 2016) allowed us to form the term "geoecological transformation of river basin" as change driven by the influence of the natural and anthropogenic factors of ecological condition of aquatic objects on drainage of rivers, which leads to subsequent changes in: biocenoses, hydrological regime of watercourse, stream bed deformations, etc.

Materials and methods.

Methods of the study were based on primary empirical researches, the so-called "protocol propositions" which consist of recording the results of singular observations. During 2019-2020 the authors selected water samples from the ponds of the Zhovtenka River. The samples were taken four times in four different seasons of the year. We performed laboratory studies with assessment of the general level of mineralization, chlorides and sulfates in the water, visual diagnostic observations, including taking photos of current condition of the aquatic objects. In the research we used mathematical and analytical methods of analysis of the obtained results using modern geoinformational systems and software complexes QGIS and Microsoft Excel.

Results and discussion.

The Zhovtenka River (Fig. 1) is a typical small river of the basin of the Dnipro. It runs through the territory of Sofiivka and Apostolove Districs of Dnipropetrovsk Oblast. The length of the river without tributaries is 42 km. The area of the drainage accounts for 293 km^2. The average stream gradient is 1.5 ‰.

The river`s runoff is formed chiefly by the atmospheric precipitations on average amounting to 400-430 mm annually. The greatest average monthly discharges of water are observed in March-April, the least (almost zero) – in late summer or early autumn. River recharge by groundwater is low and not sustainable.

Active use of the lands around the basin of the Zhovtenka River began in the late XVIII and early XIX centuries. Already at that period, try pattern of the climate and deficiency of aquatic resources determined the necessity of creating ponds for guaranteed water supply throughout the year. The ponds were small in size and were made directly near the settlements. Until the mid-XIX century, there were 2 small ponds on the stream bed of the river and 2 more on the tributaries. In the mid-XX century the number of ponds was 6. By the early XXI century, the quantity of the ponds had increased up to 31, including 16 facilities in the stream bed of the river and 15 on the tributaries. Furthermore, one water reservoir of $3.547 \cdot 10^6$ m^3 capacity has been built in the ravine of the Vovcha. According to the data of technical inventory checking, the total extent of the regulation of the Zhovtenka River accounted for $6.393 \cdot 10^6$ m^3.

Within the framework of the studies, we carried out field studies of separate hydrological parameters of the Zhovtenka River: characteristics of the runoff (water discharges) of the river and saline content in the water. To assess the hydrological parameters, we determined 10 control stations in the upper and middle flow of the river, both the stream bed and the tributaries.

Monitoring results of visual examination indicate that there was no water seepage in the lower canal pounds of the levees in all the control stations during the period from May 2019 to February 2020. The content of chlorides and sulfates, and also mineralization of water in the ponds do not depend on the order of installment of the stations, but there was seen a tendency towards increase in the concentration during the period of observations.

Fig. 2 presents average data on concentration of chlorides, sulfates and mineralization of water in ponds in 10 control stations of the upper and middle parts of the basin of the Zhovtenka River. Mean mineralization of water in the ponds may be compared to mineralization of water in the Azov Sea.

It has to be noted that one of the causes of high mineralization may have been the water from the retention pond of discharge water effluent from the water treatment facilities of Kryvy Rih and which was used for irrigation. At the same time, their overall mineralization did not exceed 1500 mg/dm^3, and the system of irrigation and water pumping was destroyed in the mid 90s. An additional factor was chemical analyses of water in ponds located upstream, where there is seen high content of dry residuals. Thus, we can state that the situation with significant deterioration of quality of water resources is much more complex in character. The factors of impact include economic development in the territories, which causes influx of a large amount of polluting substances; the long period of irrigated agriculture which affects the discharge of highly-mineralized drainage water into the river; construction of a large amount of artificial water bodies which have completely obstructed the current of the river and turned it into a cascade of evaporators, resulting in violation of the conditions necessary for sanitary water norms. During the warm period,

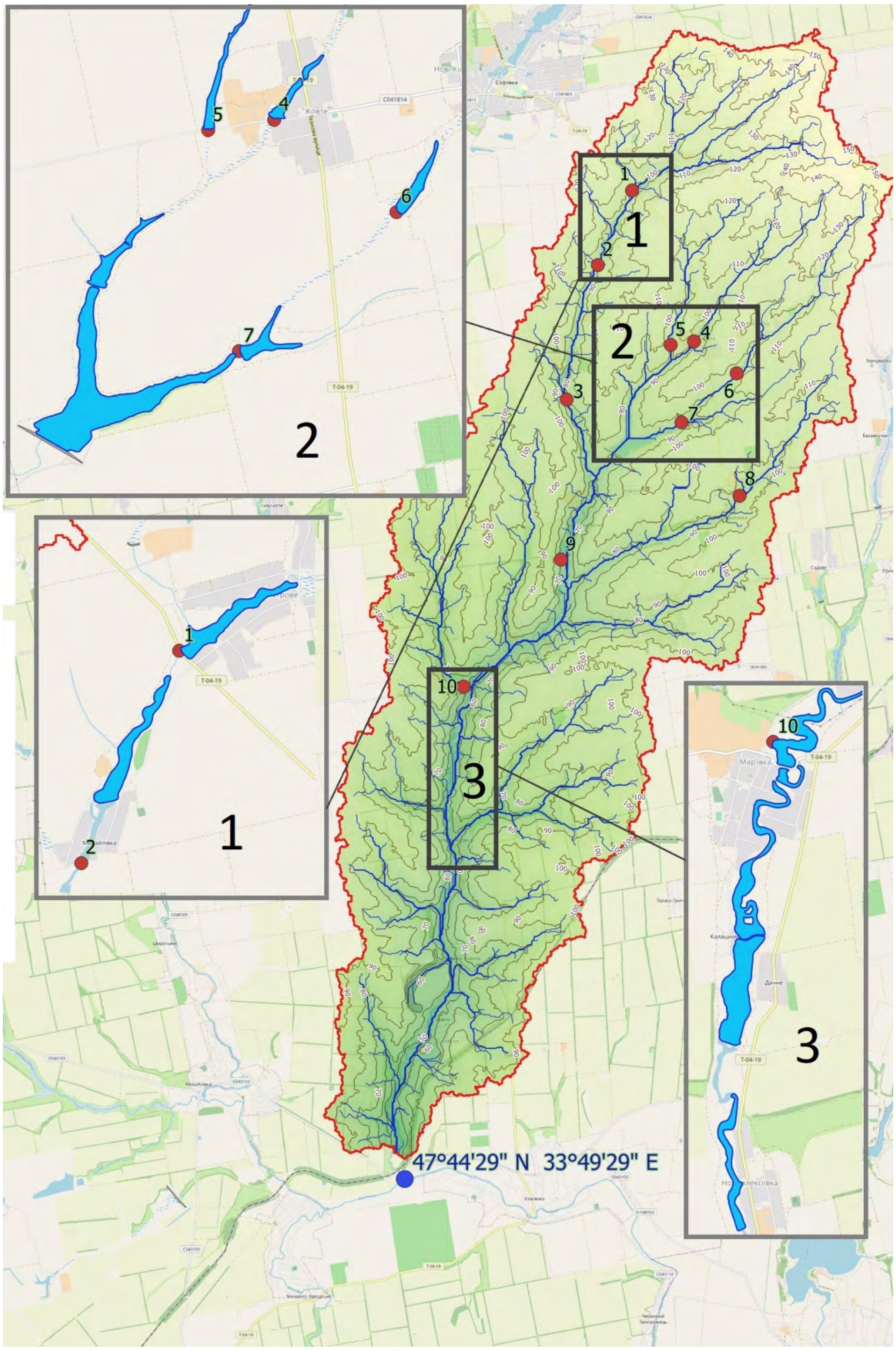
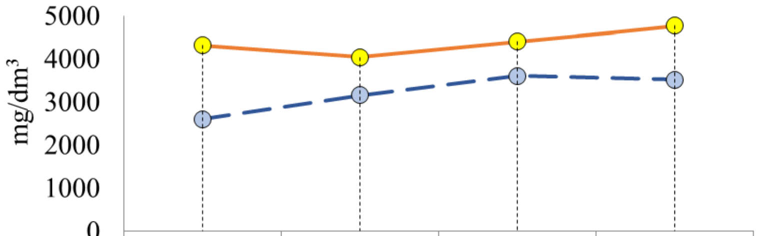


Fig. 1. Geoinformational network of the Zhovtenka River with points of selection of water samples (performed by the authors using geoinformational system QGIS)

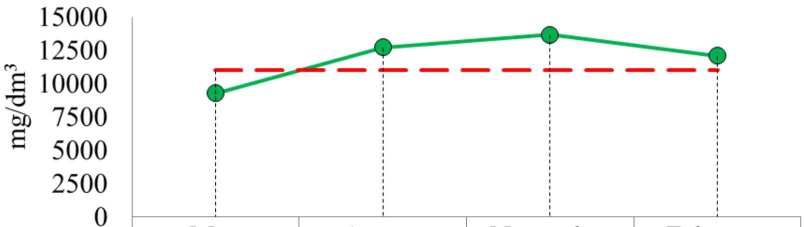
the concentration of dry residuals in the water bodies increases, while oxygen-saturation decreases. All the mentioned factors create conditions for negative geo-ecological transformation of the river basin and loss of self-cleaning ability of the river. The assessment of the impact of each separate element may be a relevant task for further studies. Fig 3 presents parameters of mineralization of water in the ponds which sequentially located along the current in the stream of the Zhovtenka River.

The obtained parameters of mineralization of water suggest that the ponds are functioning as evaporation ponds. These conclusions are supported by the fact that the loss of runoff due to additional evaporation from the water surface of the ponds and small water reservoirs reduces the water resources in the Steppe zone by 5-7% in averagely humid years and by 20-40% in low-moisture years (Yatsyk et all., 1991). As an example, Fig. 4 presents the dynamics of degradation of a water body in the basin of the Zhovtenka.



	May	August	November	February
Chlorides	2602	3161	3614	3514
Sulfates	4312	4039	4401	4769

a



	May	August	November	February
Mineralization	9254	12688	13683	12039
Azov Sea	11000	11000	11000	11000

b

Fig. 2. Mean parameters of saline content (a) and mineralization of water (b) in the ponds of the basin of the Zhovtenka River (sampling took place in 2019-2020 in the authors` survey).

Obviously the water with high salt content does not meet the requirements to water quality for drinking and agricultural water supply. According to the criteria of assessment of quality of irrigation water, as regulated by the National Standard of Ukraine DSTU [*Ukr*. ДСТУ] 2730:2015 "Quality of natural water for irrigation. Agronomic criteria", water in the ponds is not appropriate for irrigation. It is also inappropriate for fish breeding. Thus, one can state absence of conditions for observance of ecologically safe water use in the basin of the Zhovtenka.

The field and laboratory surveys substantiate the necessity of further analysis of the situation with use of geoinformational systems and mathematical methods of analysis. To assess the level of geoecological transformation of the basin of the Zhovtenka River, the authors have for the first time proposed introducing the coefficient of the river fragmentation (K_{fr}) and other assessment parameters which may be used to compare the impact parameters along the length or across the area of a surveyed object. Coefficients of geoecological impact are frequency of anthropogenic changes in the ecosystem which no doubt has a close relationship with the degree of the geoecological transformation of the river basin:

1) Coefficient of fragmentation of the river is suggested to be calculated using the ratio of the total number of artificial aquatic objects to the length of the river or the area of the territory (administrative region, district, drainage basin) where they are located:

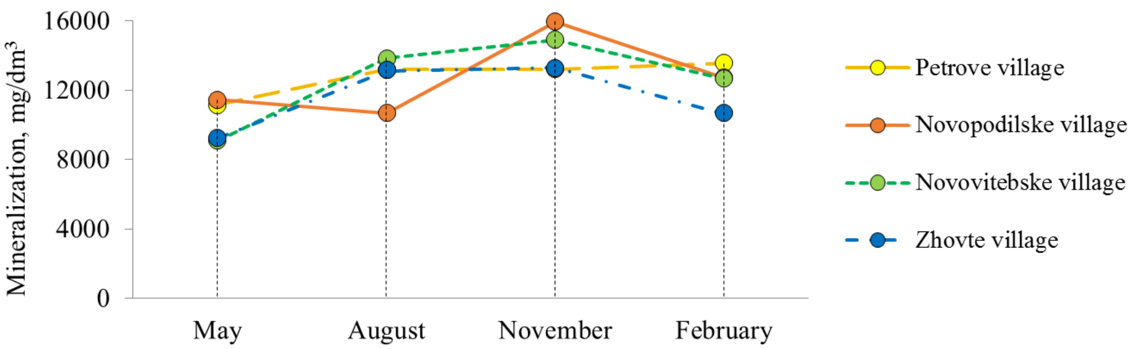


Fig. 3. Dynamics of the changes in mineralization of water in the ponds of the upper part of the basin of the Zhovtenka River (the samples were taken in the settlements in 2019-2020, the authors` survey)

$$K^{l}_{fr} = \frac{N}{L}, \quad (1)$$

$$K^{s}_{fr} = \frac{N}{S}, \quad (2)$$

where L – length of the river, km; S– the area of the territory, km^2; N – total amount of the levees on the river.

2) The coefficient of urbanization of the river – ratio of the length of the settlements along the bank strip of the river or ratio of the area of the urbanized territory to the drainage area of the river basin:

$$K^{l}_{urb} = \frac{L_{urb}}{L_{rb}}, \quad (3)$$

$$K^{s}_{urb} = \frac{S_{urb}}{S_{rb}}, \quad (4)$$

where L_{urb} – the length of the territory along the bank line of the river where construction has been done, km; L_{rb} – the length of the river basin; S_{urb} – the area of the urbanized territory, km^2; S_{rb} – drainage area of the river basin, km^2.

3) Coefficient of alienation of hydrographic network as a result of the economic activity and exhaustion of the outlets of the river network and the tributaries of different order:

$$K^{l}_{pr} = \frac{L_{pr}}{L_{rb}}, \quad (5)$$

$$K^{s}_{dpr} = \frac{S_{dpr}}{S_{rb}}, \quad (6)$$

where L_{pr} – is the length of elements of hydrographic network which were ploughed (are currently in the land use) as a result of economic activity, km; S_{drb} – the area of the alienation of the elements of the hydrographic network of the territory, km^2.

Implementation of the proposed approach allowed us to determine the main elements of assessment. We determined that 18 ponds are located on the river, and the total amount of the objects in the river basin is 34. We should note that field surveys and use of GIS-technologies allowed us to determine more hydrotechnical facilities than there are recorded in the declared data of passportization in the management institutions, which is 31 artificial water bodies. Within the drainage basin, there are 16 settlements (Fig. 5).

Quantitative characteristics of the constituents of the formulae (3-6) were determined through the analysis of digital model of drainage (DMD) of the Zhovtenka River in GIS QGIS and combined visual analysis of high-quality cosmic images (Google Earth). Particularly, the length and area of the ploughed hydrographic network was estimated using geomorphological and hydrological analyses of drainage in GIS, differentiative buffer analysis of hydrographic network outside the range of the water course and gully-ravine system (Fig. 6).

Table 1. Determined parameters of the main geoecological elements of the basin of the Zhovtenka River.

Total length of the river, L, m	Total length of hydrographic network of the river basin L_{rb}, km	Drainage area, S_{rb}, km^2	Area of the territories undamaged by economic activity (meadows, pastures, forests), S, km^2	Number of artificial water objects, N	Area of urbanized territory (settlements), S_{urb}, km^2	length of the territory along the bank line of the river where construction has been done, L_{urb}, km	Length of the elements of gully-ravine network which have been damaged by economic activity, L_{pr}, km	Area of loss of the elements of hydrographic network, S_{dtb}, km^2
42	161	293	16.65	34	21	29	150	3.0

Through the calculations we determined that the total parameter of coefficient of the fragmentation of the river by artificial water bodies is 0.212. The calculation of this parameter only along the length of the river itself (not taking into account the tributaries) equaled 0.429, which is twice higher. That means a pond per each 2 km. If we consider the natural ecological condition of the river and its drainage basin as a conditional 1, and further gradually substract all the components of the negative impact, we shall receive the following results:

Taking into account all coefficients of negative impact for the length 1-0.212-0.180-0.482=0.126, i.e. only 12.6% of the river is in conditionally natural state;

Taking into account all coefficients of negative impact for the area (without consideration of agricultural lands) 1-0.116-0.072-0.010=0.802.

The area of the lands of the aquatic fund, particularly shoreline-protective strips and protected aquatic zone is the main parameter which characterizes the geoecological transformation of the river basin. Such a territory being in the natural condition of drainage

a

b

c

d

Fig. 4. Dynamics of degradation of the water reservoir in the Vovcha Ravine on the Zhovtenka River (dates when images were taken): a – 04.07.2010, b – 21.09.2017, c – 10.03.2020 (source – Google Earth), d – 01.03.2020 (source – author`s photo)

with meadows, pastures and forests accounts for only 16.65 km² or 5.7%.

ploughing. Around 94% of the drainage area of the Zhovtenka River basin has been drastically damaged by economic activity. The negative impact along the river`s length was seen on over 87% of the length of the hydrographic network.

Table 2. Calculation of parameters of geoecological impact of economic activity in the basin of the Zhovtenka River.

Coefficient of river fragmentation		Coefficient of urbanization of the river		Coefficient of alienation of hydrographic network	
Along the length	Across the area	Along the length	Across the area	Along the length	Across the area
K^{l}_{fr}	K^{s}_{fr}	K^{l}_{urb}	K^{s}_{urb}	K^{l}_{pr}	K^{s}_{dpr}
0.212	0.116	0.180	0.072	0.482	0.010

Conclusions.

The results of the field surveys of the Zhovtenka River indicate that agricultural activity in the river basin exerts a destructive impact on the condition of its ecosystem.

As a result of intensive arable farming all the outlets of the streams and watercourses of the hydrographic network of the river basin, accounting for the total length of 150 km, have been damaged by ploughing.

The main factors of the destructive processes include irrational construction of a large number of ponds, which has had an extremely negative effect on the discharge characteristics of the river and self-cleaning ability. The river has been transformed into a cascade of evaporation ponds, the quality of water

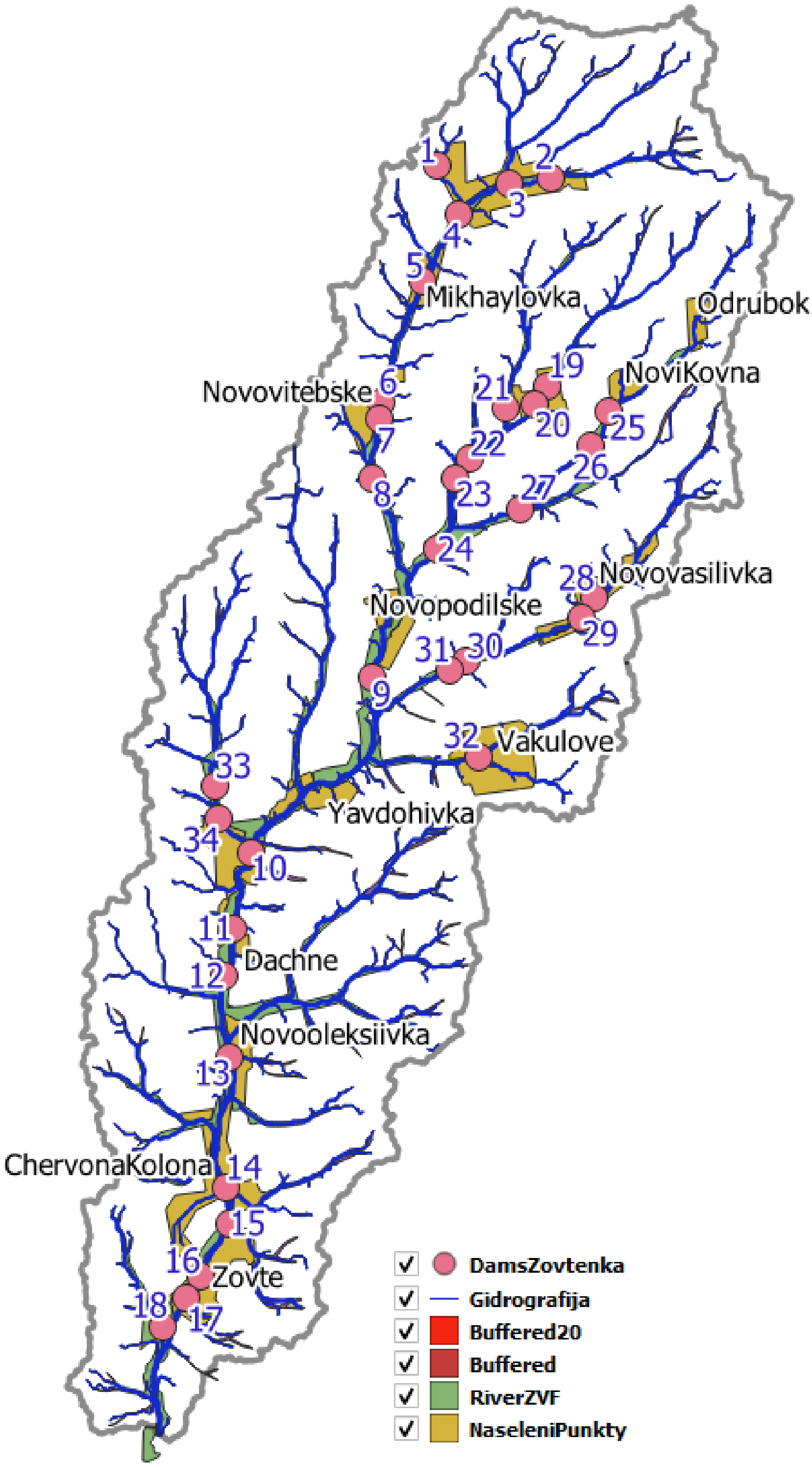


Fig. 5. Results of the surveys of the impact of economic activity on geoecological transformation of the river basin of the Zhovtenka using QGIS geoinformational system (authors` development).

in which does not meet the requirements for use for economic purposes.

To restore the hydrological regime and geoeconomic condition of small rivers, it is relevant to carry out further surveys with the purpose of determining the actual number of artificial water bodies and perform ecological-economic substantiation of expedience of their further use.

It is necessary to evaluate how the norms of the current water protection legislation are fulfilled, particularly the requirements of the Water Code of Ukraine as determined in article 82 “Regulation of the runoff of the rivers, creation of artificial water bodies”.

Today, there are no generalized results of evaluation of ecological condition of small rivers of

a b c

Fig. 6. To determine length and areas of ploughed hydrographic network: a – photo of the northern part of the drainage (Google Earth); b – automated determination of hydrographic network by analysis of data of DMD in QGIS; c – buffer analysis of ploughed erosive areas according to the range of water stream (ravine).

Dnipropetrovsk Oblast and the majority of the water courses of the Steppe zone of Ukraine. Therefore, it is necessary to consider the possibilities to restart the work on passportization of small rivers of Dnipropetrovsk Oblast, which has not been conducted since the early 1990s.

Thus, coefficients of the geoecological impact of economic activity are recommended to be used as criteria of assessment of: the extent of anthropogenic impact; category of complexity and class of consequences (responsibility) of the objects of hydrotechnical infrastructure (construction); during development of projects for assessment of impact on the environment; results of monitoring surveys, etc.

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Assessment of the geo-ecological potential of the landscape districts (on the example of Sumy region, Ukraine)

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Abstract. The article is devoted to the study of the life potential support of the population, which reflects living conditions of the population in specific geosystems (on the example of the Sumy region, Ukraine). The main purpose of the article is to assess the geo-ecological potential of the regional landscape structures, namely the landscape districts of the Sumy region. The article highlights the theoretical and methodological foundations of the geo-ecological potential research, substantiates the theoretical aspects of the of "geo-ecological potential" concept, describes in detail the methodology of assessing geo-ecological potential, which is evaluated on the basis of natural geosystem potential, geosystem sustainability potential and technogenic geosystem load. The assessment of the natural potential of the Sumy region landscape districts (based on the humidity coefficient, the sum of active temperatures above 10°C, hydrothermal potential of phytomass productivity, annual precipitation, adverse natural processes such as landslides, flooding, rising groundwater levels, erosion, dry winds, hail, fogs) is conducted and the levels (low, below average, average and high) of the natural potential are defined. Three districts of the environmental sustainability of the regional landscape districts are established on the basis of component-by-component assessment of the meteorological potential of the atmosphere, surface water and soil sustainability potential, as well as biotic potential: below average, average and above average. The indicators of the population density of the region, coefficient of the territorial production concentration, economic development of lands (agricultural lands, built-up lands and open lands without vegetation), environmental pollution of the region (radiation and chemical air pollution, pollution of natural waters and soils) and the integrated indicator of technogenic load, which allows to establish the following levels of the technogenic load on the landscape districts of the region: below average, average and above average, are analyzed. Particular attention is paid to the assessment of the geo-ecological potential, which allows to establish 5 levels, of which only 3 are presented in Sumy region, based on which areas of geo-ecological potential of the landscape districts are identified: below average, average and above average and a map of the geo-ecological potential areas is created. It is established that the indicator of the geo-ecological potential of the landscape districts of the Sumy region ranges from 0.05 Psel-Vorskla landscape district (below average level) to 1.07 Esman'-Kleven' landscape district (above average level). It is established that the higher the values of the natural potential and sustainability of the natural environment and the lower the indicators of technogenic load, the higher are the values of the geo-ecological potential.

Key words: geo-ecological potential, natural potential, sustainability of natural environment, technogenic load, landscape district, Sumy region.

Оцінка геоекологічного потенціалу ландшафтних районів (на прикладі Сумської області, Україна)

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Анотація. Стаття присвячена дослідженню потенціалу життєзабезпечення населення, яке відображає умови життя населення в конкретних геосистемах (на прикладі регіону України – Сумської області). Головна мета статті полягає в оцінці геокологічного потенціалу регіональних ландшафтних структур регіону, а саме ландшафтних районів Сумської області. У статті висвітлені теоретико-методичні засади дослідження геоекологічного потенціалу, обгрунтовані теоретичні аспекти поняття «геоекологічного потенціалу», детально описана методика оцінки геоекологічного потенціалу, який оцінюється на основі природного потенціалу геосистеми, потенціалу стійкості геосистем та техногенного навантаження на геосистеми.

Здійснено оцінку природного потенціалу ландшафтних районів Сумської області та виокремлено низький, нижче середнього, середній та високий рівні природного потенціалу. Встановлено 3 ареали стійкості природного середовища ландшафтних районів регіону на основі покомпонентної оцінки метеорологічного потенціалу атмосфери, потенціалу стійкості поверхневих вод та ґрунтів, а також біотичного потенціалу: нижче середнього, середній та вище середнього. Проаналізовано показники густоти населення регіону, коефіцієнту територіальної концентрації виробництва, господарського освоєння земель, забруднення навколишнього середовища території регіону та обраховано інтегральний показник техногенного навантаження, що дозволяє встановити наступні рівні техногенного навантаження на ландшафтні райони регіону: нижче середнього, середній та вище середнього. Особлива увага приділяється оцінці геоекологічного потенціалу, що дозволяє встановити 5 рівнів, з яких лише 3 представлені для Сумської області, на основі яких виокремлено ареали геоекологічного потенціалу ландшафтних районів: нижче середнього, середній і вище середнього та створено картосхему ареалів геоекологічного потенціалу. Встановлено, що показник геоекологічного потенціалу ландшафтних районів Сумської області коливається від 0.05 Псельсько-Ворсклинський ландшафтний район (рівень нижче середнього) до 1.07 Есмань-Клевенський ландшафтний район (рівень вище середнього). Встановлено, що чим вищі значення природного потенціалу та стійкості природного середовища та нижчі показники техногенного навантаження, тим вищі значення геоекологічного потенціалу.

Ключові слова: геоекологічний потенціал, природний потенціал, стійкість природного середовища, техногенне навантаження, ландшафтний район, Сумська область

Introduction.

"Geo-ecological potential" is defined as the potential for life support of the population, which reflects conditions and quality of life of the population in specific geosystems (Olishevska, 2009). It synthesizes the natural (natural resource) potential, the level of anthropogenic impact on natural complexes and their resistance to anthropogenic loads. As a result of the interaction of nature and society in the process of nature management, a geo-ecological situation is formed, which is a kind of indicator of the quality of the natural environment of society in a specific space-time situation. The leading role in determining the living conditions of society belongs to the geo-ecological potential (GP), because the higher the natural resource potential, sustainability of the natural environment, the lower are the risks of negative impact of the technogenic load. The value of GP to some extent reflects geo-ecological living conditions of the population, so studies of this kind are extremely relevant. On the other hand, based on the natural component, GP is determined by the properties of natural-territorial complexes (landscapes). In this context, the territory of the Sumy region is no exception, so it is important to consider and assess the geo-ecological potential of the regional landscape structures, in particular landscape districts.

The purpose of the study is to assess GP of the landscape districts of the Sumy region, which is implemented through a number of tasks: to characterize the natural potential of the landscape districts of the region; to establish sustainability of their natural environment; to find out the technogenic load on the regional landscape structures; to calculate the geo-ecological potential of each landscape district, to identify the levels of geo-ecological potential and to carry out zoning of the territory of the Sumy region by the GP size.

Materials and methods of research.

In a broad sense, the term "potential" is interpreted as opportunities, available forces, stocks that can be used for anything. Scientists-geographers use the term potential to refer to the properties of natural territorial complexes that are important in terms of human economic activity, such as natural potential, natural resource potential, recreational potential, ecological potential, environmental potential, sustainability potential, and so on.

In a broad sense, GP is defined as the quality of human habitat, the ability to provide the necessary food, working and leisure conditions (recreational resources) and treatment (climate therapy, balneological resources) (Olishevska, 2009). It (potential) determines the geo-ecological living conditions of people in certain geosystems and reflects the ability of the landscape to be a favorable environment for people and a source of resources used by society.

The theoretical basis of the GP study is set out in the works of A. Isachenko (Isachenko, 1992), O. Marynych (Marynych and Shyshchenko, 2005), I. Nesterchuk (Nesterchuk, 2011), Yu. Olishevska (Olishevska, 2005), P. Shyshchenko (Shyshchenko, 1993), and others. The methodological foundations of its study are substantiated in the works of V. Baranovskyi (Baranovskyi, 2001), I. Nesterchuk (Nesterchuk, 2011), Yu. Olishevska (Olishevska, 2005).

The value of GP reflects the state of geosystems and has two components: natural-ecological and socio-economic. The natural-ecological component reflects the natural-ecological potential, which is determined on the basis of indicators of natural potential and sustainability of the natural environment, and socio-economic – the value of technogenic load on geosystems, which includes the indicators of land development and environmental pollution. The disadvantage of this approach is its certain subjectivity, but in many cases, it is the only one possible and therefore it is the most used.

The integrated indicator of GP is determined by the formula (1):

$$GP=NP+R-TL \quad (1)$$

where GP – geo-ecological potential, NP – natural potential, R – potential of geosystems resistance to technogenic load, TL – technogenic load on the geosystems (Olishevska, 2005).

In a broad sense, natural potential is a set of available natural conditions and resources that affect economic activity and are used or can be used in the production of goods, as well as are able to meet the needs of the country or humanity (Cheremkha, 2012). By "natural potential" we mean the intrinsic natural property of NTC, which it has in relation to any function, regardless of whether it is performing it at this time or not. The integrated indicator of the natural potential is determined by the formula (2):

$$NP = P+T+C_{hum}+C_{hp} - (ANP) \quad (2)$$

where NP – natural potential, P– annual precipitation, T – sum of active temperatures above 10°C, C_{hum} – humidity coefficient, C_{hp} – hydrothermal potential of phytomass productivity, ANP – adverse natural processes.

The study and assessment of the natural potential of the regional landscape structures was carried out on the basis of the methodology proposed by Yu. Olishevska and I. Nesterchuk (Olishevska, 2005; Nesterchuk, 2011). This methodology involves several stages: analysis of the main climate indicators, namely heat and moisture of the territory, as these factors have direct ecological significance and determine the territorial differentiation of other indicators, including biological (annual precipitation, humidity coefficient, sum of active temperatures above 10°C, hydrothermal potential of phytomass productivity) (values of indicators are taken from the corresponding maps); detection and analysis of adverse natural processes and assessment of their joint manifestation (values of indicators are taken from the corresponding maps). Since these indicators have different size, they are normalized with subsequent calculation of the values of NP according to the formula (2). Based on the calculated data, a scale of natural potential levels is developed.

M. Grodzynskyi, V. Baranovskyi, P. Shyshchenko (Grodzynskyi, 1995; Baranovskyi, 2001; Shyshchenko, 1999) studied the sustainability of the natural environment. They repeatedly mentioned in their works and actively emphasized the need to study the sustainability of geosystems, as the completeness of the geo-ecological research is impossible without taking it into account. The essence of the concept of "sustainability" is revealed in the monograph of M. Grodzynskyi, where the author showed the full range of interpretations of sustainability, identified its basic forms and found out that sustainability of the geosystem is the ability of the latter, in the case of external factors, to be in one state district and return to it due to inertia and reproducibility, as well as to move due to plasticity from one district of states to others, without going beyond invariant changes during a given time interval (Grodzynskyi, 1995).

Methodological bases for determining the natural environment sustainability were developed by V. Baranovskyi and P. Shyshchenko. When determining the sustainability index, the unidirectionality of its components is taken into account, and the sustainability potential is calculated on the basis of component-by-component assessment of the meteorological potential of the atmosphere, surface water and soil sustainability potential, as well as biotic potential and is calculated by the formula (3):

$$S=A+W+S+B \quad (3)$$

where S – potential for environmental sustainability, A – meteorological potential of the atmosphere, W – surface water sustainability potential, S – soil sustainability potential, B – biotic potential.

The meteorological potential of the atmosphere characterizes predominance in the atmosphere of the processes of accumulation or dispersion of chemicals and compounds. Assessment of the soil sustainability is performed according to indicators that characterize the sums of active temperatures, slope steepness, structure, resistivity, mechanical composition, humus content, type of water regime, pH reaction, afforestation, ion capacity, plowing, economic development within the natural agricultural areas of the regions of Ukraine. When determining the surface water sustainability, the days with water temperature above +16°C, water color indices and average long-term water consumption had been taken into account. Biotic potential characterizes the property of geosystems to preserve or restore biological diversity. According to the methodology of Yu. Olishevska, indicators of the resistance of the natural environment to the technogenic impact are taken from the map of V. Baranovskyi and P. Shyshchenko "Sustainability of the natural environment" (Baranovskyi and Shyshchenko, 2002). Based on the data analysis, a scale of environmental sustainability levels is developed.

The technogenic load is a degree of direct and indirect impact of people and economy on nature as a whole and its individual components. Analysis of the technogenic impact on the environment is a complex process due to the variety of forms of human impact on it. There are different approaches to the establishment of the technogenic load on the environment, but the most successful, in our opinion, are the methods of V. Baranovskyi and I. Nesterchuk (Baranovskyi, 2001; Nesterchuk, 2011), as they are best suited for assessing the technogenic load within regional landscape structures. The indicator of the technogenic load is calculated by the formula (4):

$$TL = SEDT + EP \quad (4)$$

where TL – technogenic load, SEDT – socio-economic development of the territory, EP – environmental pollution.

The value of the technogenic load is characterized by the indicators of socio-economic development of the territory, namely: population density, territorial concentration of production and economic development of land. This indicator was calculated by the formula (5):

$$SEDT = PD + C_{t.c.p.} + EDL \quad (5)$$

where SEDT – socio-economic development of the territory, PD – population density, $C_{t.c.p.}$ – coefficient of the territorial concentration of production, EDL – economic development of lands.

In order to calculate the indicators of socio-economic development of the territory the data from the Main Department of Statistics in the Sumy region (Holovne upravlinnia statystyky…, 2019) and the Main Directorate of the State Geocadastre in Sumy region (Holovne upravlinnia Derzhheokadastru…, 2019) were used. The indicator of economic development of lands was calculated as the sum of shares of agricultural lands, built-up lands and open lands without vegetation.

In addition to socio-economic development of the territory, the environmental pollution, namely radiation pollution, chemical pollution of air, natural waters and soils is important for a comprehensive analysis of the technogenic load, which was calculated by the formula (6):

$$EP = P_r + P_{at} + P_w + P_s \quad (6)$$

where EP – environmental pollution, P_r – radiation pollution of plants and soils, P_{at} – chemical pollution of the air, P_w – pollution of natural waters, P_s – chemical pollution of soils.

The analysis of the technogenic load on geosystems of the regional level needs generalized indicators. Due to the fact that for such areas it is quite difficult to collect information on specific indicators of the technogenic impact, the data are taken in terms of administrative districts and approximately calculated for landscape districts, taking into account the share of administrative districts within physical and geographical areas.

The integrated indicator of the technogenic load is calculated as the sum of normalized indicators: population density, coefficient of the territorial concentration of production, economic development of lands and environmental pollution of the landscape districts. On the basis of the received values of an indicator the levels of the technogenic load are developed.

An important stage of the study is to determine the integrated indicator of GP of the regional landscape structures, which included a number of procedures. At the first stage the normalization of the indicators of natural potential, the potential of natural environment sustainability and technogenic load of the landscape districts of the region is carried out. Next, the integrated indicator of GP is calculated, and its levels are set: low (-1…-0.60), below average (-0.59…-0.20), average (0.21–0.80), above average (0.81–1.40) and high (1.41–2.00).

These levels of GP were calculated for regional landscape structures – landscape districts that reflect the local characteristics of the hydro-functioning of the soil-plant complex and, as a consequence, form an individual landscape-morphological structure of the territory (Neshataev et al., 2005). During the study, the schemes of physical-geographical zoning developed by O. Marynych and others (Marynych et al., 2003), B. Neshataev (Neshataev, 1987; Neshataev et al., 2005) and V. Udovychenko (Udovychenko, 2003) were used.

Results and discussion. Assessment of natural potential.

The indicator of the sum of active temperatures above 10°C increases in the direction from north to south: northern, Znob-Novhorod landscape district is characterized by minimal values (2380°C), southern districts – (Transvorsklian, Lypova-Dolyna-Nedryhailiv, Lebedyn-Zinkiv – by maximal values (2650°C, 2600°C and 2640°C, respectively) (Veklych, 1995). The amount of precipitation increases in the opposite direction – from south to north. Their maximal number is received in the northern landscape districts: Znob-Novhorod and Esman'-Kleven' (600 mm per a year), and moving to the south, the amount of precipitation decreases, and in Lebedyn-Zinkiv district reaches the minimal annual amount (546 mm) (Veklych, 1995). Calculations of the humidity coefficient have established that the northern districts: Znob-Novhorod (1.2) and Shostka-Yampil'

(1.16) have excessive humidity, and the southern ones: Lypova-Dolyna-Nedryhailiv (1.0), Lebedyn-Zinkiv (1.0) – sufficient humidity. The hydrothermal potential of phytomass productivity determines the ability of the landscape to produce biomass and is estimated on the basis of the ratio of average annual productive humidity, vegetation period to average annual radiation balance (Baranovskyi, 2001). Landscape districts that have a relatively high indicator of hydrothermal potential of phytomass productivity include: Znob-Novhorod (6.0), Shostka-Yampil' (6.0), Seim (5.9) and Esman'-Kleven' (5.9), lower indicators are typical for Lebedyn-Zinkiv (5.3) and (Transvorsklian) (5.3).

Adverse natural processes can be found in the Sumy region quite widely and in various forms. The most common adverse natural processes include landslides, flooding, rising groundwater level, erosion, dry winds, hail, fog, and so on. The most eroded landscape districts are: Psel-Vorskla (soil erosion reaches up to 60%), Esman'-Kleven', Lebedyn-Zinkiv and Lypova-Dolyna-Nedryhailiv (up to 40%) (Veklych, 1995). At the same time, the lowest degree of soil erosion is observed in the northern districts of the region, while in the forest-steppe part of the region the intensity of erosion processes is much higher, which is manifested in greater depth of river valleys, density of ravine-beam network, one of the reasons for which is decreasing forest area. Landslides are characteristic primarily of Psel-Vorskla (17 landslide-prone areas have been identified), Seim (16) and Lebedyn-Zinkiv (11) landscape districts (Danylchenko, 2019). Not the last among the adverse processes is flooding, which occurs during significant spring floods and rainy years. The main reason for this phenomenon is the rise in groundwater levels, associated with significant over-regulation and siltation of rivers. The largest areas affected by flooding are Seredyna-Buda (1100 ha), Krolevets (448 ha) and Yampil' (350 ha) administrative districts, in terms of basins of the main rivers of the region the first positions are occupied by the basins of the Desna, Vorskla and Seim rivers, which territorially correspond to Znob-Novhorod, Shostka-Yampil', Transvorsklian and Vyry landscape districts (Danylchenko, 2019). Manifestations of such an adverse phenomenon as hail can most often be found in Vyry, Psel-Vorskla and Transvorsklian landscape districts (3 days per year). Dry winds are most common in the south of the region, namely in Transvorsklian (10 days per year), Lebedyn-Zinkiv (9 days per year) and Psel-Vorskla (8 days per year) landscape districts, they are less common in the northern districts. The distribution of fogs is uneven throughout the Sumy region, but also has a certain pattern: it decreases from north to south. The maximal number of days with fog is in Znob-Novhorod, Shostka-Yampil', Sula, Lypova-Dolyna- Nedryhailiv and Esman'-Kleven' landscape districts (60 days per year or more), which have a sufficient and even excessive level of humidity. In the south of the region, in the Transvorsklian and Psel-Vorskla landscape districts, the number of days with fog is 57 (Veklych, 2005).

The calculated indicators of the natural potential are in the range from 0.54 to 2.68 and according to the methodology (Nesterchuk, 2011) correspond to the following levels (Table 1).

The low level of the natural potential (<0.95) is represented in 3 landscape districts: Lypova-Dolyna-Nedryhailiv ancient glacial hilly-beam area, Lebedyn-Zinkiv gently undulating terraced and Psel-

Table 1. Levels of the natural potential of the landscape districts of the Sumy region

№	Landscape district	Calculations of normalized indicators*	Level of natural potential
1.	Znob-Novhorod	3 – (2.6/8) = 2.68	High
2.	Shostka-Yampil'	2.47– (2.64/8) = 2.14	High
3.	Seim	1.4 – (3.9/8) = 0.97	Below average
4.	Sula	2.4 – (2.7/8) = 2.07	High
5.	Lypova-Dolyna-Nedryhailiv	1.06 – (2.7/8) = 0.73	Low
6.	Lebedyn-Zinkiv	0.9 – (2.9/8) = 0.54	Low
7.	Transvorsklian	1.8 – (3.95/8) = 1.31	Below average
8.	Esman'-Kleven'	2.2 – (2.85/8) = 1.85	Average
9.	Vyry	1.9 – (4.5/8) = 1.34	Below average
10.	Psel-Vorskla	1.4 – (4.9/8) = 0.79	Low

*Note: calculations of normalized indicators are carried out according to the formula: $NP = \sum_i^4 V_s - \frac{\sum_j^8 V_d}{8}$,

where $У_s$ – normalized values of indicators-stimulators of the NP (annual precipitation, sum of active temperatures above 10°C, humidity coefficient, hydrothermal potential of phytomass productivity), $У_d$ – normalized values of indicators-destimulants of the NP (joint manifestation of adverse natural processes: flooding, rising groundwater levels, exogenous geological processes, landslides, erosion, recurrence of dry winds, hail, fog).

Vorskla off-glacial elevated strongly dissected area. These areas are characterized by low indicators of hydrothermal potential of phytomass productivity, worse climatic conditions (minimum precipitation – 546 mm is in Lebedyn-Zinkiv landscape district). Due to the fact that adverse natural processes (such as landslides (maximum number – 17 per Psel-Vorskla landscape district), soil erosion (maximum 60 % is typical for Psel-Vorskla district, 40 % – for Lebedyn-Zinkiv and Lypova-Dolyna-Nedryhailiv) and dry winds (9 days per year dominate in the Lebedyn-Zinkiv landscape district)) are widespread in the territory (Danylchenko and Hupalo, 2017), the level of natural potential will be low.

The level below average (0.96-1.50) is also typical for 3 districts: Seim terraced weakly dissected, Transvorsklian terraced gently undulating dissected, Vyry glacial-periglacial dissected landscape districts. The normalized indicators are higher than in the areas of the previous level, especially if we take into account the climatic indicators (the maximum amount of heat receives Transvorsklian landscape district). The Seim landscape district is characterized by a high indicator of hydrothermal potential of phytomass productivity. Adverse natural processes are represented by rising groundwater levels (Vyry landscape district is the leader in terms of indicators – 13 ha), flooding (maximal value falls on Transvorsklian district), soil erosion (35 % is typical for Vyry and Seim landscape districts) and frequent hail (Vyry and Transvorsklian landscape districts suffer from it 3 days a year).

The average level of the natural potential (1.51-2.00) is peculiar only to 1 landscape district – Esman’-Kleven’ glacial dissected district, where the most precipitation (600 mm per year) falls, the hydrothermal potential of phytomass productivity is 5.9. Due to a small number of adverse natural processes, among which it is necessary to distinguish soil erosion (up to 40 %) and frequent fogs (60 days per year), the NP of Esman’-Kleven’ reaches an average level of 1.85.

The high level of the natural potential (>2.01) is is peculiar to 3 districts: Znob-Novhorod moraine-zander weakly drained, Shostka-Yampil’ elevated weakly dissected and Sula elevated-dissected landscape districts. These districts have high values of annual precipitation (600 mm – Znob-Novhorod district, 598 mm – Sula), the coefficient of humidification of the territory is represented by the maximal indicators: in Znob-Novhorod landscape district is 1.2 and Shostka-Yampil’ – 1.16. The hydrothermal potential of phytomass productivity reaches a maximal value equal to 6.0 in Znob-Novhorod and Shostka-Yampil’ landscape districts. Among the unfavorable natural processes it is necessary to note only flooding (maximal values are typical for Znob-Novhorod and Shostka-Yampil’ landscape districts) and frequent fogs (60 days per year). Due to the high values of climatic indicators and the minimal number of adverse processes, these landscape districts received maximal indicators of the NP, ranging from 2.07 to 2.68.

Table 2. Sustainability of the natural environment of the landscape districts of the Sumy region (Hupalo and Danylchenko, 2018)

№	Landscape district	Meteorological potential “A”	Potential of the surface water sustainability “W”	Potential of the soil sustainability “S”	Biotic potential “B”	Sustainability potential “S”
1.	Znob-Novhorod	A_3	W_2	S_1	B_4	-1.21 (below average)
2.	Shostka-Yampil’	A_2	W_2	S_2	B_3	-0.5 (below average)
3.	Seim	A_2	W_2	S_3	B_3	+0.5(average)
4.	Sula	A_2	W_2	S_3	B_3	+0.095 (aver-age)
5.	Lypova-Dolyna-Nedryhailiv	A_2	W_2	S_3	B_3	+0.55 (average)
6.	Lebedyn-Zinkiv	A_2	W_2	S_3	B_3	+0.6 (average)
7.	Transvorsklian	A_2	W_2	S_3	B_3	+1.12 (above average)
8.	Esman’-Kleven’	A_2	W_2	S_2	B_3	+0.26 (average)
9.	Vyry	A_2	W_2	S_3	B_3	+0.85 (above average)
10.	Psel-Vorskla	A_2	W_2	S_3	B_3	+0.99 (above average)

Note: meteorological potential: A_3 (0.96-1.25) – below average, A_2 (0.66-0.95) – low; surface water sustainability potential: W_2 (0.006-0.1) – low; soil sustainability potential: S_1 (40 and less) – very weak, S_2 (41-50) – weak, S_3 (51-60) – medium; biotic potential: B_4 (5.6-6.5) – average, B_3 (4.6-5.5) – below average.

Assessment of the environmental sustainability.

Based on the analysis of data (indicators of meteorological potential of the atmosphere, the potential of surface water and soil sustainability, biotic potential) taken from the map (Baranovskyi and Shyshchenko, 2002), according to the methodology, 3 districts of environmental sustainability of the landscape districts of the Sumy region are outlined: below average (indicator of sustainability potential is less than -0.50); average (-0.49...+0.80) and above average (+0.81...+2.10) (Table 2).

The area of the natural environment resistance to the technogenic load below average includes 2 landscape districts: Znob-Novhorod (-1.21) and to a greater extent Shostka-Yampil' (-0.5). These districts were referred to this group due to the low value of meteorological potential A_3 (below average), low surface water sustainability potential W_2, soil sustainability potential S_1 and S_2, which are characterized as very weak and weak soils, as well as average and below average biotic potential B_4 and B_3.

The second area of environmental sustainability with an integrated average indicator includes 5 landscape districts: Seim (+0.5), Sula (+0.095), Lypova-Dolyna-Nedryhailiv (+0.55), Lebedyn-Zinkiv (+0.6) and Esman'-Kleven' (+0.26). Indicators of some components of the natural environment sustainability of this area have higher values: the potential of soil sustainability has passed into the gradation (weakly stable) S_2, and for most landscape districts is characterized by a higher indicator of soil sustainability (medium stable) S_3. The value of meteorological potential varies from below average to low A_2. The value of the surface water sustainability potential has not changed – W_2 is low. Biotic potential also changed its value and moved to a group below average – B_3.

The third area of the above average environmental sustainability includes 3 landscape districts: Transvorsklian (+1.12), Psel-Vorskla (+0.99) and Vyry (+0.85). The indicators of the meteorological potential, surface water sustainability potential and biotic potential have not changed compared to the previous area and are A_2, W_2, W_3, respectively, but the value of soil sustainability potential is only in gradation S_3 and corresponds to "medium stable". The main role in determining habitats by the degree of the natural environment sustainability is played by the soil sustainability potential.

Assessment of the technogenic load.

The initial stage of the study of socio-economic development of the region is the analysis of the development of the territory. Examining the population density as a component of socio-economic development of the territory, we clearly trace the highest value (112.1 people/km^2) in the Psel-Vorskla landscape district, as it borders the regional center, and the lowest (13.0 people/km^2) in the Znob-Novhorod landscape district. The coefficient of the territorial concentration of production, as well as population density, fixed the maximum value for Psel-Vorskla landscape district (0.940), while Znob-Novhorod received the minimal value (0.009), because compared to the previous district the number of enterprises and production scale is much lower.

Economic land development (agricultural land, built-up land, open land without vegetation) is most represented in Vyry landscape district (87 %), where the largest share of developed land, and the minimal – in Znob-Novhorod landscape district (63.5 %).

A significant share in the technogenic load has environmental pollution. The Lebedyn-Zinkiv landscape district (normalized indicator 5.09) is characterized by the maximal pollution indicator, where there is an increased content of Pb and Cd in soils, chemical pollution of water and air, as well as the Psel-Vorskla landscape district (4.7), and the minimal indicator is typical for the Znob-Novhorod landscape district (2.23).

Calculations of the integrated indicator of the technogenic load allow us to identify the following levels of technogenic load (Table 3).

The level of the technogenic load *below average* (<2.40) is typical for one landscape district – Znob-Novhorod (indicator 2.23), in which there is the minimal population density, territorial concentration of production, economic development of land, and, consequently, minor environmental pollution.

The *average* level of the technogenic load is typical for 4 landscape districts – Seim (4.18), Sula (4.09), Esman'-Kleven' (2.86) and Vyry (3.78). Compared to the previous level, they have higher rates of economic development of land, population density, while the indicator of environmental pollution is not critical.

The level of the technogenic load above average is typical for 5 landscape districts: Shostka-Yampil' (4.82), Lypova-Dolyna-Nedryhailiv (4.78), Lebedyn-Zinkiv (5.62), Transvorsklian (4.71) and Psel-Vorskla (7.06). These landscape districts are characterized by high rates of the population density, territorial concentration of production, economic development of the territory, but most of them are united by high rates of environmental pollution. Psel-Vorskla landscape district stands out the most from the above-mentioned areas. It occupies a leading position in terms

Table 3. Levels of the technogenic load on the landscape districts of the Sumy region (Hupalo and Danylchenko, 2018)

№	Landscape district	Socio-economic development of the territory						Environmental pollution, integrated value	Integrated indicator of the technogenic load	Level of the technogenic load
		Population density, people/km^2	Normalized value	$C_{t.c.p.}$	Normalized value	Economic development of lands,%	Normalized value			
1.	Znob-Novhorod	13.0	0	0.009	0	63.5	0	2.23	2.23	Below average
2.	Shostka-Yampil’	47.9	0.35	0.139	0.13	67.0	0.15	4.19	4.82	Above average
3.	Seim	72.4	0.6	0.142	0.13	86.0	0.95	2.5	4.18	Average
4.	Sula	21.5	0.08	0.092	0.09	85.4	0.93	2.99	4.09	Average
5.	Lypova-Dolyna-Nedryhailiv	15.8	0.03	0.020	0.01	84.2	0.88	3.86	4.78	Above average
6.	Lebedyn-Zinkiv	35.0	0.22	0.058	0.05	69.7	0.26	5.09	5.62	Above average
7.	Transvorsklian	56.5	0.44	0.075	0.07	81.1	0.74	4.2	4.71	Above average
8.	Esman’-Kleven’	32.3	0.19	0.068	0.06	72.2	0.36	2.25	2.86	Average
9.	Vyry	31.9	0.19	0.032	0.02	87.0	1	2.57	3.78	Average
10.	Psel-Vorskla	112.1	1	0.940	1	72.1	0.36	4.7	7.06	Above average

of the population density, territorial concentration of production and environmental pollution.

Assessment of the geo-ecological potential.

Calculation of GP of the landscape districts of the Sumy region and establishment of its levels, allow to group landscape districts into certain groups by homogeneity of size of the investigated indicator and to create the map of GP areas of the region (fig. 1).

It is established that the GP indicator of the landscape districts of the Sumy region varies from 0.05 Psel-Vorskla landscape district (below average level) to 1.07 Esman’-Kleven’ landscape district (above average level) (Table 4).

The area of the *low level of the geo-ecological potential* on the territory of the Sumy region is not represented, because the state of natural resources of the region is assessed as satisfactory, and the technogenic load is not reflected as critical.

The area of the *below average level of the geo-ecological potential* unites 2 landscape districts: Lebedyn-Zinkiv and Psel-Vorskla. These are the central districts of the region, with the total area of about 4969 km^2 (21 % of the region’s territory), densely populated, economically developed, industrially developed with a technogenic load, which is 1.4 times higher than the regional average. In these districts there are low and below average levels of natural potential, due to low hydrothermal potential of phytomass productivity, unfavorable climatic indicators (Lebedyn-Zinkiv landscape district has a minimal value of precipitation and humidity),

Table 4. Geo-ecological potential of the landscape districts of the Sumy region

№	Landscape district	NP	Normalized value	S	Normalized value	TL	Normalized value	GP	Levels of the geo-ecological potential
1.	Znob-Novhorod	2.68	1	-1.21	0	2.23	0	1	Above average
2	Shostka-Yampil’	2.14	0.74	-0.5	0.3	4.82	0.53	0.51	Average
3.	Seim	0.97	0.2	+0.5	0.73	4.18	0.40	0.53	Average
4.	Sula	2.07	0.7	+0.095	0.45	4.09	0.38	0.77	Average
5.	Lypova-Dolyna-Nedryhailiv	0.73	0.08	+0.55	0.75	4.78	0.52	0.31	Average
6.	Lebedyn-Zinkiv	0.54	0	+0.6	0.77	5.62	0.7	0.07	Below average
7.	Transvorsklian	1.31	0.35	+1.12	1	4.71	0.5	0.85	Above average
8.	Esman’-Kleven’	1.85	0.6	+0.26	0.6	2.86	0.13	1.07	Above average
9.	Vyry	1.34	0.4	+0.85	0.88	3.78	0.32	0.96	Above average
10.	Psel-Vorskla	0.79	0.11	+0.99	0.94	7.06	1	0.05	Below average

and the significant impact of adverse natural soil erosion (40 % is typical for Lebedyn-Zinkiv and 60 % for Psel-Vorskla landscape districts), landslides (17 in Psel-Vorskla) and dry winds (9 days per year in Lebedyn-Zinkiv). The level of environmental sustainability of the area is defined as “average” for Lebedyn-Zinkiv and “above average” for Psel-Vorskla landscape districts, due to the low potential of the surface water sustainability (W_2) and below the average value of biotic potential (B_3). Instead, the level of the technogenic load for these landscape districts is defined as “above average”, as it is aggravated by high population density, the coefficient of territorial concentration of production, which, in turn, is closely related to environmental pollution and accompanied by deteriorating air, natural waters, flora and land resources. This area is characterized by minimal values of geo-ecological potential of 0.07 for Lebedyn-Zinkiv and 0.05 for Psel-Vorskla landscape districts, which is by 10 times lower than the regional average.

The area of the *average level of the geo-ecological potential* includes 4 landscape districts: Seim, Shostka-Yampil’, Sula and Lypova-Dolyna-Nedryhailiv, which, stretching from the northwest to the central part of the region, cover an area of about 10485 km^2, which is 44 % of the region. This area is characterized by a moderate population density, extensive economic development of lands, with an indicator of the technogenic load, which is almost the same as the regional average (4.4). The natural potential of the above-mentioned landscape districts, due to high climatic indicators, hydrothermal index of phytomass productivity and the minimal number of adverse natural processes is characterized by a high level, except for Lypova-Dolyna-Nedryhailiv and Seim landscape districts.

The level of environmental sustainability of most landscape districts is “average”, due to the low potential of surface water resistance (W_2) and below the average value of biotic potential (B_3), only Shostka-Yampil’ district belongs to the level of stability “below average” due to low meteorological potential (A_2). The level of the technogenic load “above average” is typical for Shostka-Yampil’ landscape district, where there are high indicators of population density and territorial concentration of production, affecting environmental pollution, and for Lypova-Dolyna-Nedryhailiv landscape district, where this indicator is quite high due to the high value of the economic development of lands and the integrated indicator of environmental pollution and is accompanied by irrational human economic activity. The level of the technogenic load of Seim and Sula landscape districts is “average” due to the significant indicators of the population density and economic development of lands, although the integrated indicator of the environmental pollution is one of the most insignificant in the region. This district is characterized by the average value of the geo-ecological potential (0.53), including the Seim landscape district – 0.53, Sula – 0.77; Shostka-Yampil’ – 0.51; Lypova-Dolyna-Nedryhailiv – 0.31, which is closed to the regional average (0.6).

The area of the *geo-ecological potential of the above average level* includes 4 landscape districts: Esman’-Kleven’, Transvorsklian, Vyry and Znob-Novhorod. This area is not widespread in the Sumy region, but mainly formed in the east of the region. The total area is about 8324 km^2, which is 35 % of the region with different indicators of natural potential, with a predominance of the above average and average levels of environmental sustainability, relatively low population, extensive economic development of lands and technogenic load, which is lower than the average in the region. In these landscape districts there is: a high level of natural potential in Znob-Novhorod due to the high climatic indicators (maximal precipitation, humidity coefficient) and relatively insignificant manifestation of adverse natural processes; the average level has been achieved in Esman’-Kleven’ district, due to high values of some climatic indicators (precipitation 600 mm per a year) and insignificant combined manifestation of adverse natural processes, among which we should single out soil erosion and fog; the below average level is typical for Transvorsklian and Vyry landscape districts, due to the minimal values of some climatic indicators and the widespread manifestation of adverse natural processes, including flooding, rising groundwater levels and hail. The level of environmental sustainability for Znob-Novhorod landscape district is recorded as “below average”, due to the low potential of soil sustainability (S_1), for Esman’-Kleven’ – as “average” due to low meteorological potential (A_2), soil sustainability potential (S_2), for Transvorsklian and Vyry landscape districts, it is defined as “above average” due to low meteorological potential (A_2) and surface water sustainability potential (W_2). The level of the technogenic load for Znob-Novhorod landscape district is “below average”, due to the minimal indicators of population density, territorial concentration of production, economic development of lands, and, accordingly, environmental pollution. For Vyry and Esman’-Kleven’, technogenic load is characterized by “average” level, as these landscape districts do not have a powerful industry, which, in

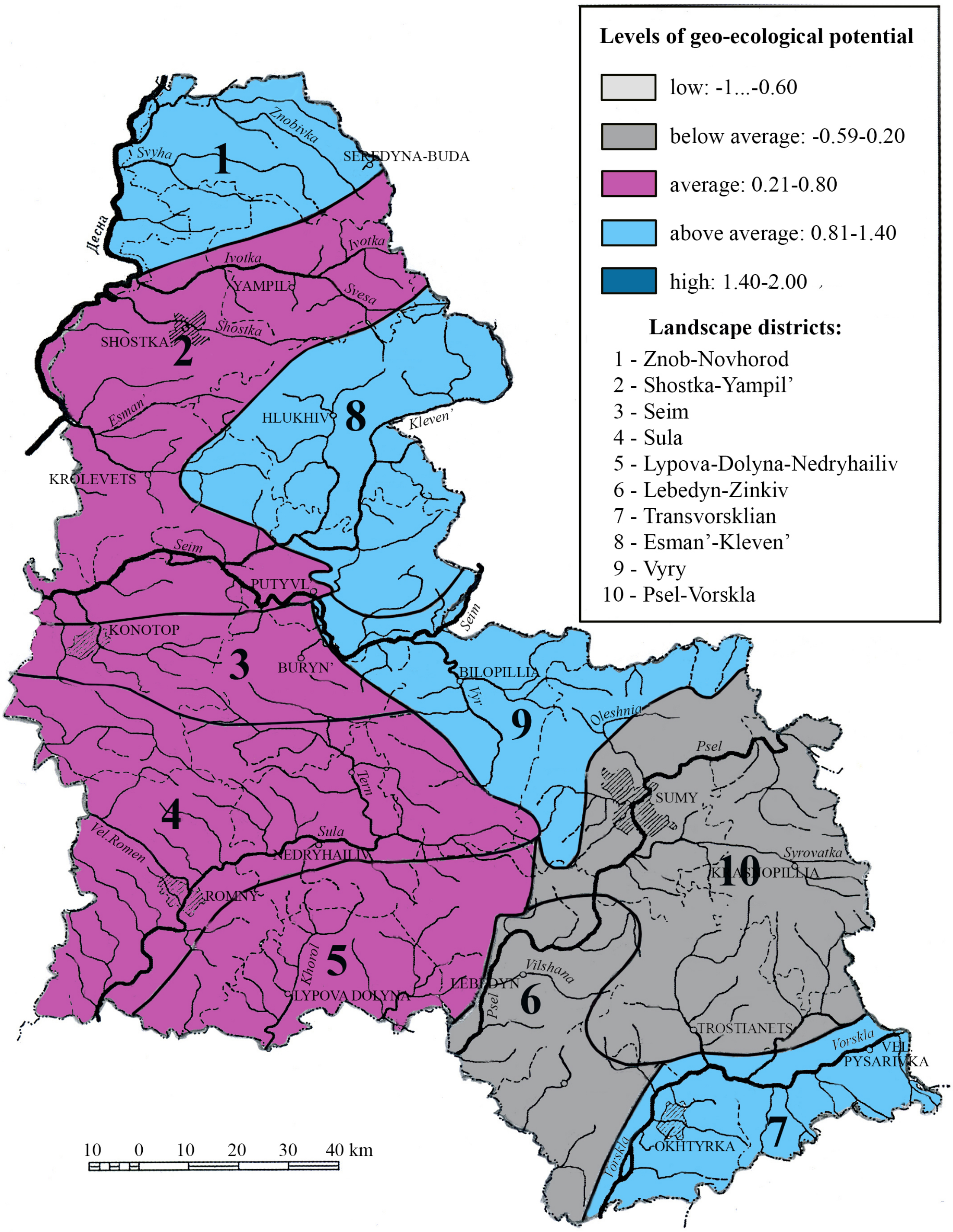

Fig. 1. Geo-ecological potential of the landscape districts of the Sumy region

turn, reduces the demographic and, consequently, technogenic impact on the natural environment of the region. This area is characterized by the maximal values of the GP (average – 0.97), namely: 1.07 for Esman'-Kleven', 1 for Znob-Novhorod, 0.96 for Vyry and 0.85 for Transvorsklian landscape districts, which 1.6 times higher than the regional average. With all the diversity of the natural potential levels, environmental sustainability and technogenic load, it was possible to establish a certain peculiarity: the main role in high indicators of the geo-ecological potential is played by low indicators of the technogenic load.

The area of the *geo-ecological potential of the high level* is characterized by comfortable living conditions of the population with minimal impact of the technogenic load. In the course of the study, this area of GP was not identified.

Conclusions.

Geo-ecological potential is the potential of life support of the population, which reflects the living conditions of the population in specific geosystems.

The value of the geo-ecological potential is estimated on the basis of natural potential of geosystems, potential of geosystems resistance to the technogenic load and technogenic load on geosystems. The natural potential of the landscape districts of the Sumy region is determined, and the low, below average, average and high levels of natural potential are distinguished. The analysis of the natural environment sustainability of the landscape districts of the Sumy region is calculated on the basis of indicators of geosystems resistance to the technogenic impact.

In the course of the study 3 areas of environmental sustainability of the landscape districts of the Sumy region were identified: below average, average and above average. The integrated indicator of the technogenic load allows to establish the following levels of the technogenic load: below average, average and above average. The assessment of the geo-ecological potential allows to establish the levels on the basis of which the areas of the geo-ecological potential of landscape districts are determined. 5 levels of the geo-ecological potential have been identified, and only 3 of which are presented for Sumy region and a map of the areas of the geo-ecological potential has been created. It is found out that the higher the values of the natural potential and sustainability of the natural environment and the lower the indicators of the technogenic load, the higher are the values of the geo-ecological potential, with the decisive role of the minimal anthropogenic impact. The results of the study provide an opportunity to assess the internal regional capabilities of the landscape districts, as well as to identify areas for the most/least favorable living conditions.

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Estimating environmental risk assessment for drinking and fisheries use (on the example of the Danube river – the city Vilkovo)

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Abstract. The Danube is a source of water for the household and industrial needs of Ukrainian population, industry and agriculture. The Danube waters are used for drinking centralized water supply in the cities of Kiliya and Vilkovo, as well as fisheries in the region. Therefore, it was important to carry out the "Environmental Risk Assessment for Drinking and Fisheries Use (on the example of the Danube River –the city Vilkovo)". The purpose of the study was to evaluate the effectiveness of the application of the environmental risk criterion R on the basis of hydrochemical observations to verify the safety of drinking and fishery use. Analysis of environmental problems of the lower Danube River - Vilkovo; assessment of the environmental situation; calculation of water quality risk indicators according to the methodology of the Institute of Market Problems and Economic and Environmental Research of the NAS of Ukraine; establishing a link between water quality and risk is the finding of the research. It is established that the environmental situation is "critical" due to suspended substances, phenols, manganese and HCC for drinking water supply and "strained" through chromium, manganese, HCC, copper for fishery use. An assessment of the water quality by the modified Water Pollution Index (IWM) showed that the water is "moderately polluted" and "contaminated". For both types of water use, normalized aggregated pollution indices were calculated taking into account the likelihood of a risk event occurring and R risk indicators were determined by year. It is established that there is a close linear relationship between WSS and R. It is shown that environmental risk estimates, based on the probability of exceeding concentrations of pollutants above the MPC, reflect well the ecological status of the water.

Keywords: *hydrochemical indicators, Danube, drinking and fishery use, ecological risk, maximum permissible concentration, hydrochemical pollution index, ecological situation, security*

Оцінювання екологічних ризиків для питного та рибогосподарського використання (на прикладі р. Дунай – м. Вилкове)

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Анотація. Дунай - це джерело води для господарсько-побутових потреб населення, промисловості, сільського господарства України. Води Дунаю використовуються для питного централізованого водопостачання міст Кілія та Вилкове, також значний розвиток у регіоні має рибальство. Тому актуально було виконати «Оцінювання екологічних ризиків для питного та рибогосподарського використання (на прикладі р. Дунай - м. Вилкове)». Метою дослідження була оцінка ефективності застосування критерію екологічного ризику R на основі даних гідрохімічних спостережень для перевірки безпеки питного та рибогосподарського використання. Завдання роботи: аналіз екологічних проблем нижньої течії річки Дунай – м. Вилкове; оцінка екологічної обстановки; розрахунок показників ризиків якості води за методикою інституту проблем ринку та економіко-екологічних досліджень; встановлення зв'язків між показниками якості води та ризику. Установлено, що екологічна обстановка є «критичною» через завислі речовини, феноли, манган та ХСК для питного водопостачання та «напруженою» через хром, манган, ХСК, мідь для рибогосподарського користування. Оцінка якості води за модифікованим індексом забруднення води (ІЗВм) показала, що вода є «помірно забруднена» та «забруднена». Для обох видів водокористування були розраховані нормовані агреговані індекси забруднення з урахуванням ймовірності настання ризикової події та визначені показники ризику R по роках. Установлене існування тісного лінійного зв'язку між ІЗВм та R. Показано, що оцінки екологічних ризиків, розрахунки яких базуються на ймовірностях перевищення концентрацій забруднювальних речовин над ГДК, добре відображають екологічний стан води.

Ключові слова: гідрохімічні показники, Дунай, екологічний ризик, індекси забруднення, екологічна обстановка, забезпеченість.

Introduction.

The Danube is the largest river in Western Europe (length is 2960 km, basin area is 817 thousand km^2). There are 19 countries fully or partially located within the river catchment (Our Waters, 2007), and its value for 80 million people is difficult to overestimate (WWF, 2002).

A small section of the Danube River (170 km) from Reni to its mouth runs through the territory of Ukraine. Above the Romanian city, the Tulcea River is divided into three branches (Kiliysky, Sulinsky, and Georgievsky) and flows into the Black Sea. The most waterlogged of them is the Kiliysky sleeve (129 km^3 / year) passing through the border area of Romania and Ukraine (Lozovitskyi, 2015).

The Danube Delta is included in the WWF (Global-200) list of the most valuable sites on Earth. In the northeastern part of it there is the Danube Biosphere Reserve, where 4300 species of fauna and flora are inhabited (WWF, 2002), dozens of which are on the verge of extinction. Delta ecosystems are a source of valuable natural resources.

On the other hand, the Danube is a source of water for domestic and industrial needs of Ukrainian population, industry and agriculture. The total water abstraction from the river within Ukraine exceeds 2 billion m^3, and the number of water users is about 150 (WWF, 2002). Danube waters are used for drinking centralized water supply in the cities of Kiliya and Vilkovo (Rehionalnaprohrama; Safranov, & Chuhai, 2017), and fisheries have significant development in the region.

Ukraine is lagging behind the developed countries in terms of average life expectancy, and high mortality is largely related to the consumption of poor drinking water. (Krainiukov, &Yakusheva,2016). About 80% of drinking water supply in Ukraine is from surface water bodies, in which water according to hydrochemical pollution indicators has the III-IV quality class - moderately polluted and polluted water (Khvesyk,&Yarotska, 2004). Therefore, it was important to carry out the "Environmental Risk Assessment for Drinking and Fisheries Use (on the example of the Danube River – the city Vilkovo)". The purpose of the study was to evaluate the effectiveness of the application of the environmental risk criterion R, which was calculated on the basis of hydrochemical observations. The objective of the work was to analyze the environmental problems of the lower Danube - Vilkovo; assessment of environmental conditions and water quality; calculation of water quality risk indicators according to the methodology of the Institute of Market Problems and Economic and Environmental Research, Odessa; establishing a link between water quality and risk.

Literature review.

In the mid-twentieth century, the banks and the lakes of the river Danube were collapsed, most of the floodplain lands and islands were converted into agricultural lands, and the water regime of the lakes became regulated. Such transformations have led to a violation of the delta's ability to filter very turbid Danube water, to precipitate sediment, to trap pollutants. All these processes affect the chemical composition of the Danube Delta water.

It is established (Khilchevskyi, 2019) that at ionic runoff of the Danube into the Black Sea 70231x10 t/year, 61 % of salts are carried out by the Kyliya branch, 20 % by Georgievsky, and 19% by Sulinsky. And the ion runoff of the entire Danube basin is 95,2 t/ km per year.

In Ukraine, scientists from the Institute of Hydrobiology of the Academy of Sciences have been engaged in research of the lower Danube for many years. In (Harchenko et al,1993) the basic regularities of formation of hydrobiological, hydrochemical and hydrological regimes of the river are shown, the question of increasing anthropogenic influence on aquatic ecosystems of the Danube is considered. The waters of the river are moderately polluted with phenol content. The pollution of the Danube water by heavy metals (copper, zinc, chromium, manganese) is characteristic with high and very high levels (Lozovitskyi, 2015). The removal of heavy metals into the river is largely determined by the impact of point sources - wastewater from municipal and industrial enterprises (Klebanov, &Osadcha, 2012).

Researchers at the Ukrainian Hydrometeorological Research Institute have shown that the greatest amount of nitrogen in the Danube ecosystem comes from agriculture (Osadcha, &Klebanov, 2016)and the discharge of untreated or partially treated wastewater (OurWaters, 2007), which has a significant impact on the Danube delta ecosystem. In the shelf zone, there is a «flowering» of water in the warm season, a decrease in biodiversity and fish stocks. In the early 1990s, due to the crisis in Eastern Europe and in Ukraine, the amount of nitrogen decreased, but the state of the ecosystem did not improve (Osadcha, &Klebanov, 2016).

Specialists of the Odessa State Ecological University conducted an analysis of the main sources of anthropogenic load on natural waters of the Odessa region and an assessment of the level of surface water pollution and technogenic load on the water objects of the Odessa region by the volume of discharges of wastewater and pollutants (Chuhai, &Dzhura, 2018). The quality of the surface waters of the Odessa region, including the Danube River, is characterized as «polluted». The volume of discharges of wastewater and pollutants tends to gradually decrease the level of technogenic load from 2012 to 2016.

The report (Osadchyi, 2017) states that the results of the processing of long-term hydrochemical information obtained from the observation network of the Hydrometeorological Service of Ukraine (1989-2015), and on the basis of ecological assessment of surface water quality, can be concluded about the beginning of stabilization and some shifts towards improvement ecological status of surface waters of Ukraine in almost all river basins, including the Danube River.

The paper (Khilchevskyi, 2019) characterizes the chemical composition of river water in the Ukrainian part of the Danube basin from the standpoint of modern hydrographic zoning of Ukraine (2016) by areas of river basins.

In order to preserve the Danube ecosystem and ensure the sustainable use of its resources, an International Commission for the Protection of the Danube River Basin was established in 1998 and a program of the Transboundary National Monitoring Network (TNMN) (Joint Danube Survey 2, 2008). In 2002, Ukraine acceded to the Convention for the Protection of the Danube River, which brings together efforts by all Danube countries to reduce pollution. Phased environmental plans and their implementation, balanced management of point and diffuse discharges, will reduce pollution of the Danube.

Object, subject and research methods.

The object of the study is the hydrochemical indices of water at the Danube River - Vilkovo compared to the limit values for drinking and fishery use. The calculations were made on the basis of data from the Danube Basin Water Management on the chemical composition of water in the Danube - Vilkovo Formation for 2009-2018.

The subject of the study is to evaluate the likelihood of significant risks of water pollution in the Danube River near the drinking water intake. Environmental risk is the likelihood of an event that is caused by the impact of economic and other activities, natural and man-made emergencies and has adverse effects on the environment (Methodical Recommendations, 2016).

Research Methods: Methods for Environmental Assessment (Muzalevskiy, &Karlin, 2011); the method of calculations of the WFD modified (Snizhko, 2001); methodology of environmental risk assessment developed at the Institute of Market Problems and Economic and Environmental Research, Odessa (Methodical Recommendations, 2016).

The results of the work and their discussion.

Environmental assessment allows us to determine the ecological status of water bodies and to determine the cumulative effect of pollutants.

Standardizing the quality of the main components of the natural environment is to set limits for acceptable changes in their properties. Standards should be set by the response of the most sensitive organism-indicator, but practically most often set sanitary-hygienic or economically feasible standards (Muzalevskiy, &Karlin, 2011). The environmental quality of the pollution level is considered satisfactory if two basic conditions are met: the concentrations of the pollutants C_i should be less than their maximum permissible concentration (MPC_i) ($C_i \leq MPC_i$) and if there is a group of unidirectional substances simultaneously present in the aquatic environment, the sum of the ratio of their concentrations should be less than one (≤ 1). This condition for water bodies is determined on the basis of limiting indicators of harmfulness. In comparison with the MPC values, the ecological situation is characterized by the degree of disadvantage according to the Table 1 (Muzalevskiy, &Karlin, 2011).

Table 1. Classification of environmental conditions (Muzalevskiy, &Karlin, 2011)

Environmental Situation	Criteria for assessing the environmental situation
Relatively satisfactory	$C_i \leq MPC_i$, for all substances
Tense	$C_i \approx 10\ MPC_i$
Critical	$C_i \approx (20\text{-}30)\ MPC_i$
Crisis (environmental emergency)	$C_i > 50\ MPC_i$, Persistent negative changes in the natural environment. The disappearance of certain species of animals and vegetation. Threat to human health.
Catastrophic (environmental disaster)	Deep irreversible changes in the natural environment. Imbalance, degradation of flora and fauna, loss of gene pool. Poor health.

In the first stage of the calculations the relation was established. The number of exceedances of MPC for each hydrochemical substances was determined for the entire observation period and the empirical probabilities of exceeding the MPC were calculated (Table 2, Table 3). The empirical probability of exceeding the MPC was calculated as the ratio of the number of cases when Cu> MPC to the total number of cases (Venttsel, 1999). The MPC values were used for drinking water supply (DSTU 4808:2007) and fishery water use (Osadchyi et al, 2008).

Table 2. Empirical probability of exceeding the MPC (%) chemicals in the water in the collection area for drinking water supply at Danube River Point - Vilkovo for 2009-2018

Substance	Ci ≤ MPC	Ci ≈ 1-10 MPC	Ci ≈ 10 -50 MPC	Ci>50 MPC
Suspended matter	33	16	51	-
Nitrile Nitrogen	100		-	-
Iron	99	1	-	-
HSC	82	18	-	-
BSC_5	97	3	-	-
Chromium (VI)	100	-	-	-
Zinc	93	7	-	-
Copper	100	-	-	-
Manganese	93	7	-	-
Phenols	66	36	-	-
SPAR	100		-	-

Table 3. Empirical probability of exceeding the MPC (%) chemicals in the water for fishery use at Danube River Point – Vilkovo for the years 2009-2018

Substance	Ci ≤ MPC	Ci> 1-10 MPC	Ci ≈ 10 -50 MPC	Ci>50 MPC
Suspended matter	30	70	-	-
Nitrile Nitrogen	59	41	-	-
Iron	80	20	-	-
HSC	42	58	-	-
BSC_5	76	24	-	-
Chromium (VI)	20	80	-	-
Zinc	72	28	-	-
Copper	52	47	1	-
Manganese	29	67	4	-
Phenols	61	39	-	-
SPAR	98	2	-	-

20 substances were investigated in total. Substances such as dissolved oxygen, ammoniacal nitrogen, nitric nitrogen, phosphates, sodium, magnesium, calcium, chlorides, sulfates and petroleum products were not observed for both uses in the study period of excess MPC.

The largest chemical pollutants for drinking water are suspended substances, phenols and chemical oxygen demand (COD). It has been found that in the Danube river basin - Vilkovo for the period of 2009-2018 exceeding of the maximum permissible concentrations by 1.1 - 10 times for drinking water supply take place for phenols (36%), manganese (7%), HCC (18%) and suspended solids. For suspended substances, conditions C up to 10 MPC and C in the range of 10-50 MPC are fulfilled, exceedances of up to 10 times amounted to 16% and 10-50 times - 51%.

If not to take into account the suspended matter, it can be said that the ecological situation in the Danube - Vilkovo for water collection as drinking water supply in the studied period is in most cases «relatively satisfactory». The empirical probability of exceeding the MPC of chemicals in drinking water supply within 10-50 times more than 50% is established only for suspended substances and is 51% (Table 2). This means that taking into account the suspended matter according to the classification of the ecological situation according to the Tables 1 and 2 in the Danube formation - Vilkovo, a «critical» ecological situation was observed.

The major pollutants for fishery use are chromium, suspended solids, manganese, chemical oxygen demand, copper, nitrite nitrogen, phenols and biological oxygen consumption for 5 days (BSC_5). In the Danube River Basin - Vilkovo, for the period of 2009-2018, the excess of MPC by 1.1 - 10 times for fishery use was observed for chromium (80%), suspended solids (70%), manganese (67%), HCC (58%), copper (47%), nitrite nitrogen (41%), phenols (39%), zinc (28%), BSC_5 (24%), iron (20%). This means that the environmental situation is "tense". It should also be noted that for fisheries there were single cases of exceedances of MPC 10-50 times in copper and manganese, i.e. in some periods the environmental situation worsened to «critical».

In the second stage of the calculations, an assessment of water quality was performed according to a comprehensive indicator - the Water Pollution Index (SOI) (Osadchyi, Nabyvanets, Osadcha, &Nabyvanets, 2008). The calculation of UZV is performed on a limited number of ingredients. The modified SPI index was calculated using the following indices: dissolved oxygen, BOD5, which are mandatory, and the other four indices are the highest relative to the MPC from the list of tested substances. The SIR is calculated by the formula (Osadchyi et al, 2008, Khilchevskyi et al, 2012):

$$WFD = \frac{1}{6}\sum_{i-1}^{n}\frac{C_i}{MPC_i} \quad (1)$$

where C_i is the average concentration of one of the six water quality indicators, and the MPC_i is the maximum permissible concentration of each of the six water quality indicators.

According to the magnitudes of the calculated water sources, the water quality is evaluated. Water quality classes (Osadchyi et al, 2008) are distinguished as follows: I - very pure (WFD ≤0,2); II - pure (WFD 0,2-1,0); III - moderately contaminated (WFD 1,0-2,0); IV - contaminated (WFD 2.0-4.0); V - dirty (WFD 4.0-6.0); VI - very dirty (WFD 6,0-10,0); VII - extremely dirty (WFD > 10).

The following MPCs (mg / dm^3) were used to calculate the WFD modified for drinking water supply (Table 4): suspended matter - 31.5; manganese - 0.05; HSC - 15; phenols - 0.001 (DSTU 4808:2007). WFD values (Table 4) show that according to the standards for drinking water supply, water, mainly (78%), belongs to Class IV - «contaminated». In 2012, 2015 the water quality according to the calculated index was class III - «moderately polluted».

The following MPCs (mg / dm^3) were used to calculate the WFD modified for fishery purposes water objects (Table 4): manganese - 0.01; HSC - 15; chromium - 0.001; copper - 0.001 (Osadchyi et al, 2008). WFD values (Table 4) show that according to fishery standards water belongs to the II class - «moderately polluted» - 56% and to the IV class - «polluted» - 44%.

In the next stage of calculations, the value of environmental risk is determined.

exceeds the limit value. Beyond the maximum permissible risk is the risk of catastrophic contamination (Yurasov et al, 2011).

Environmental risks are assessed by the likelihood of adverse effects on the exploitation of natural resources. In this case, the relationship between the concentration of the substance C and its MPC can be included in the quantitative estimates of risk events: (C / C_{MPC}).

Identification of pollution risks is associated with activities aimed at identifying the possibility of adverse events, changes in the quality of the aquatic environment, which impair the functionality of the water body and other consequences that can lead to any damages, losses (Methodical Recommendations, 2016, Kulachok, &Loboda, 2019).

A sufficient basis for determining the existence of a risk is the presentation of two conditions: the likelihood of occurrence of risk events and the susceptibility of the object to external influences (the possibility of receiving significant damage).

When solving the risk assessment tasks, the R values are calculated based on the determination of the concentration ratio of the pollutant and its MPC (Methodical Recommendations, 2016):

$$R \cong C_i > C_{MPC}, \quad (2)$$

Table 4. Modified WFD index in Danube basin - Vilkovo for 2009-2018

Year	2009	2010	2011	2012	2013	2014	2015	2017	2018
for drinking water supply									
WFDm	2.58	3.15	2.00	1.69	2.68	2.70	1.90	2.08	3.24
for fishery purposes									
WFDm	1.42	1.40	1.43	2.38	2.26	2.10	1.58	1.81	2.36

Environmental risk is the likelihood of an event occurring, which is caused by the negative impact of economic and other activities, natural and man-made emergencies and has adverse effects on the environment (Loboda, &Otchenash, 2017).

A risk event is defined as an undesirable event that can harm the environment, human health (Methodical Recommendations, 2016). Any economic or other decisions should be made in such a way that they do not exceed the limits of the harmful effects on the environment. Sometimes it is difficult to set them because the thresholds for the influence of many anthropogenic and natural factors are unknown.

The permissible environmental risk is the risk of environmental damage when the concentrations of pollutants do not exceed the MPC. The maximum risk arises when the concentration of the pollutant

$$R = C_i / C_{MPCi} > 1, \quad (3)$$

$$R = C_{MPCi} / C_i > 1, \quad (4)$$

where C is the concentration level of the i-th contaminant; R is a quantitative indicator of risk; SGCI is the maximum permissible concentration for the i-th contaminant. SGDi is assigned depending on the type of water user (DSTU 4808:2007, Osadchyietal., 2008). In identifying the risks of environmental and human health damage in the event of environmental contamination with several independent chemicals, a standardized aggregated pollution index can be used in the form (Metodychnirekomendatsii, 2016) of:

$$, \quad \bar{R} = \sum_{i=1}^{n} \frac{C_i}{C_{MPCi}} \frac{N_{ai}}{Ni} > 1, \quad (5)$$

where n - is the number of chemicals considered.

Given the likelihood of a risk event, the risk indicator looks like (Metodychnirekomendatsii, 2016):

$$\bar{R} = \sum_{i=1}^{n} \frac{C_i}{C_{MPCi}} \frac{N_{ai}}{Ni} > 1, \quad (6)$$

where C_i is the concentration of the i-th contaminant; C_{MPCi} is the maximum permissible concentration; N_{ai} - the number of samples exceeding the MPC this year; N_i - the total number of samples taken per a year.

As a result of the calculations, a risk indicator for drinking water supply and fishery needs was obtained for each year (Table 5).

Table 5. Risk indicator for Danube river basin - Vilkovo for 2009-2018

Year	2009	2010	2011	2012	2013	2014	2015	2017	2018
for drinking water supply									
R	14.30	17.60	11.06	7.57	14.51	14.71	10.07	11.33	18.51
for fishery purposes									
R	8.0	7.2	6.2	12.9	11.6	11.6	7.7	9.5	13.77

When preparing management decisions related to risky events, a qualitative and quantitative assessment of possible risk situations is required. Qualitative assessment allows to evaluate possible risk areas by the following criteria: Acceptability - identification of risk acceptance; admissibility - identification of acceptable risk; criticality - identification of the zone of critical risk; inadmissibility - identification of catastrophic risk zone (Methodical Recommendations 2016).

In this technique, it is axiomatic to assume that most business results, including those that cause environmental pollution (in particular, aquatic environment), are random variables and obey a law close to normal (Gauss law). The normal law of distribution of random variables is very often used in the study of risk indicators. Checking the correspondence of the investigated random variable R for subordination to its normal distribution law is made on the basis of the Gaussian criterion (Venttsel, 1999):

$$\sigma_R / \rho_R = \sqrt{\pi/2} \approx 1{,}25, \quad (7)$$

where σ_R is the root mean square deviation of the risk index R_i from its arithmetic mean, and ρR is the arithmetic mean deviation.

The results obtained are recorded in table 6.

Table 6. Statistical parameters of a number of risk indicators R

The arithmetic mean R_{am}	Mean square deviation $σ_R$	Gaussian criterion
for drinking water supply		
13.29	3.57	1.23
for fishery purposes		
9.83	2.72	1.16

Based on the results of the calculations, it is concluded that the obtained series R for drinking water supply and fishery purposes are subject to the normal law of distribution. Using the obtained values of the R and Risk Modified Indicators, WFD modified communication graphs were constructed and linear regression equations were obtained for drinking water supply (Fig. 1) and for fishery purposes (Fig. 2).

The analysis showed that there is a close linear relationship between the risk characteristics and the water quality characteristics, which is estimated by the correlation coefficients r = 98 (Fig. 1) and r = 94 (Fig. 2). We see that the greater the WFD value, the greater the value of R, i.e., with the increase of pollution, the risk indicator increases. It also should be noted, that for both types of water use similar equations are obtained, the calculation of which is within the error of the original data.

According to the table of water quality classes, depending on the value of the WFD index and the obtained WFD and R correlation graphs (Fig. 1, Fig. 2), the correspondence of the water quality classes and the qualitative and quantitative characteristics of the level of damage was established (Table 7).

According to the R data, an empirical distribution curve of the security of this random variable was constructed (Fig. 3). Security is the probability of exceeding a given value. It is calculated by the following formula (Venttsel, 1999):

$$P = m/(k+1), \quad (8)$$

where P - is the provision; m - is the value of R in the decreasing ranked row; k - is the number of values in a row.

At the empirical curve, risk zones are highlighted (Fig. 3). Thus, in everyday practice, it is possible to determine the risk areas depending on the value assumed by the value of R, as determined by hydrochemical observations.

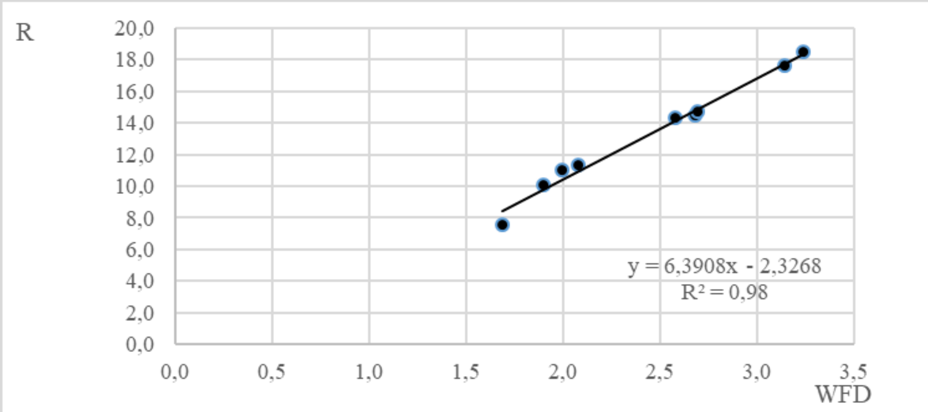

Fig. 1. Schedule of communication between R and SIC modified for drinking water supply in the Danube basin - Vilkovo, 2009–2018.

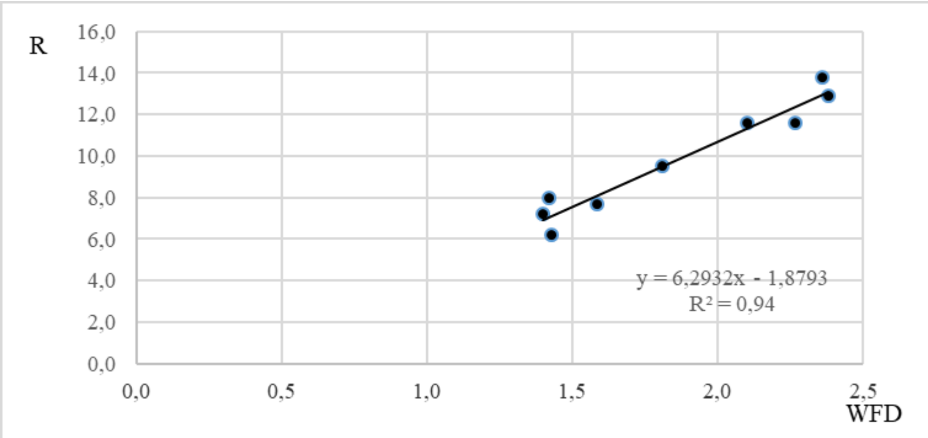

Fig. 2. Schedule for R fisheries and WFD modified for fishery purposes in the Danube Basin - Vilkovo, 2009–2018.

Table 7. Quantitative characteristics of the probability of damage

WFD	R	Quality class of water	Quality characteristic of the level of damage	Quantitative characterization of the probability of damage	Risk zone
< 0.2	< 0.5	Very pure	Extremely low	0.0-0.1	No risk
0.2-1.0	0.5-4.0	Pure	Very low	0.1-0.25	Acceptable
1.0-2.0	4.0-10.5	Moderately contaminated	Low	0.25-0.40	Affordable
2.0-4.0	10.5-23.0	Contaminated	Middle	0.40-0.60	Critical
4.0-6.0	23.0-35.0	Dirty	High	0.60-0.75	
6.0-10.0	35.0-61.0	Very dirty	Very high	0.75-0.90	Catastrophe
> 10.0	> 61.0	Extremely dirty	Extremely high	0.90-1.0	Irreversibility of the loss of an object

Conclusions.

- The main pollutants in water of the Danube River Basin - Vilkovo for the years 2009-2018 are suspended substances, phenols, manganese and HCC that limit drinking water supply. For suspended substances, the empirical probability of exceeding the MPC of drinking water supply by 10-50 times more than 50% is established, therefore the "crisis" ecological situation is determined. For fishery use, the main pollutants in the Danube River Basin - Vilkovo for the 2009-2018 years are chromium, suspended matter, manganese, HCC, copper, and nitrite nitrogen. The environmental situation is "tense".

- Assessment of water quality according to the modified WFD showed that according to the standards for drinking water supply, water was mainly (78%), grade IV quality - «contaminated»; According to fishery standards, water was classified

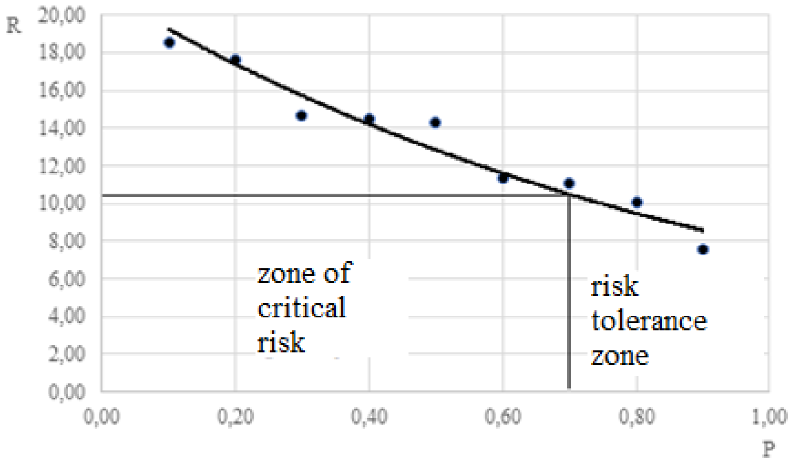

Fig. 3. Empirical curve of distribution of security of risk indicator R and selected risk zones

as class III - «moderately polluted» (56%) and class IV - «polluted» (44%).

- Normalized aggregated pollution indices were calculated for both types of water use, taking into account the probability of occurrence of a risk event and the risk indicators R for years were determined. Using the Gaussian criterion, it was confirmed that the calculated risk index R obeys the normal law of distribution.

- It is established that there is a close linear connection between WFD modified and R for drinking and fishery use (r = 99, r = 97). It is shown that the index R increases with the increase of the WFD.

- The correspondence of differentiation of the scale of water quality and qualitative and quantitative characteristics of the level of damage was established when using the risk indicator R.

- Risk zones have been established based on the construction of an empirical curve for the distribution of risk indicators. The resulting curve can be used to determine the risk zone depending on the value of the environmental risk indicator R.

- For drinking water use, R varied from 7.57 to 18.51, for fishery needs from 6.2 to 13.77. Therefore, one empirical curve for the distribution of the security of the risk indicator R was constructed and the risk zones were identified: the «tolerable risk zone» (WFD varies within 1.0–2.0) and the «critical risk zone» (WFD 2.0-4.0).

- It is shown that environmental risk assessments, based on the probability of exceeding concentrations of pollutants above the MPC, reflect well the ecological status of water and can be used to test the safety of drinking and fishery use.

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Some aspects of environmental hazard due to uranium mining in Ukraine

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Abstract. Some aspects of environmental hazard within uranium mining areas are considered. The uranium content in the environment components (rocks, soils, underground and surface waters) of the central part of the Ukrainian Shield within and beyond the uranium mining area is analyzed on the example of the Michurinske ore field. It is emphasized that man-made sources of natural origin should be considered more broadly than just waste dumps from uranium mining and processing enterprises. These are sources of ionizing radiation of natural origin, which have been subjected to concentration or their accessibility has been increased because of anthropogenic activity. Additional irradiation to the natural radiation background is formed. Waste dumps of uranium mining are considered as sources of potential dust pollution in the surface layers of atmosphere with fine dust containing uranium, its decay products and associated elements. The area of waste dumps is calculated using space images. Uranium accumulates in the dusty fraction, where its content is 0.01-0.06%. Taking into account the geological and geochemical characteristics of uranium deposits, radioactive elements, heavy metals and other associated elements of uranium mineralization are carried out of the dumps by winds and atmospheric waters with their subsequent migration into environment components. A mathematical model of potential dust air pollution in the area of long-term operation of the oldest uranium mine is presented for the summer 2019. In total, 15 factors influencing the potential threat of air dust pollution are considered and analyzed. The mathematical model is developed on the basis of the method of discriminant functions. To assess the degree of the model parameters informativeness, one-factor covariance analysis is used. It allows assessing the degree of a single sign influence on the prediction result. The developed model takes into account the area of waste dumps, uranium content in the dust fraction and wind direction southeast and/or east as the most hazardous for the study area. The model allows determining correctly the level of potential threat of air dust pollution in 96.3% ± 3.6% of all cases.

Key words: environmental hazard, uranium mining waste dumps, dust pollution, method of discriminant functions

Деякі аспекти еконебезпеки внаслідок видобування урану

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Анотація. Розглянуто деякі аспекти екологічної небезпеки в районі видобутку урану та за його межами. Проаналізовано вміст урану в компонентах довкілля (породах, грунтах, підземних та поверхневих водах) центральної частини Українського щита на прикладі Мічурінського рудного поля. Наголошено, що техногенно-підсилені джерела природного походження слід розглядати ширше, ніж просто відходи урановидобувних і переробних підприємств. Це джерела іонізуючого випромінювання природного походження, які в результаті антропогенної діяльності були піддані концентруванню або збільшилася їхня доступність, внаслідок чого утворилося додаткове до природного радіаційного фону опромінювання. Породні відвали урановидобування розглядаються як джерела потенційної запиленості приземних шарів атмосфери дрібнодисперсним пилом, який містить уран, продукти його розпаду та супутні елементи. Площа породних відвалів розраховується з використанням космічних знімків. Уран накопичується у пилуватій фракції, де його вміст складає 0.01-0.06%. З урахуванням геолого-геохімічних характеристик уранових родовищ радіоактивні елементи, важкі метали та інші елементи-супутники уранового зруденіння виносяться з відвалів вітрами та атмосферними водами з подальшою їх міграцією у компоненти довкілля. Розроблено математичну модель потенційного пилового забруднення повітря в районі довготривалого функціонування найстарішої урановидобувної шахти, за літній період 2019 року. Загалом розглянуто та проаналізовано 15 факторів, що впливають на потенційну загрозу запиленості повітря. Математичну модель розроблено на базі методу дискримінантних функцій. Для оцінки ступеня інформативності параметрів моделі був використаний однофакторний дисперсійний аналіз, що дозволяє оцінити ступінь впливу окремо взятої ознаки на результат прогнозування. Розроблена модель, що враховує площу відвалів, вміст урану в пилуватій фракції та напрям вітру південно-східний та/або східний як найбільш небезпечний для досліджуваної території, коректно дозволяє визначити рівень потенційної загрози запиленості повітря у 96,3%±3,6% усіх випадків.

Ключові слова: еконебезпека, відвали урановидобування, пилове забруднення, метод дискримінантних функцій

Introduction.

The development of mineral deposits that contain radioactive elements can lead to radioactive contamination of the territory and the formation of man-made sources of natural origin, generating alpha, beta and gamma radiation. Issues related to low-level radioactive wastes management derived from exploration, mining and processing complexes of uranium deposits and deposits enriched in radioactive elements are widely discussed in the world, as evidenced, in particular, by materials of international symposia (since 1997) on Naturally Occurring Radioactive Materials (NORM), the last of which was held in 2019 in Denver, USA.

The primary hazard to humans and the environment from natural radionuclides is associated with Technologically Enhanced NORM (TENORM), as specified in Norms of Radiation Safety of Ukraine (NRBU, 1997; TENORM, 2007). Because of man-caused activities, radioactive substances are concentrated in TENORM or their availability is increased, due to which additional to the natural background radiation occurred.

If to think of radiation hazard within the areas where the sources of TENORM are developed, then uranium mining and processing waste dumps and dust pollution of the surface atmosphere have to be considered as an urgent regional problem. Dust pollution within mining sites and beyond is mainly due to ventilation, which creates a scattering halo up to 200 m, atmospheric dust caused because of the host rocks grinding, transportation, as well as due to the long-term storage of low-level waste dumps, pollution from which also requires in-depth study.

The largest number of known uranium deposits, numerous anomalies of uranium and thorium in crystalline rocks, anomalous concentrations of uranium (up to $9 \cdot 10^{-2}$g/l) in underground waters are met in the central part of the Ukrainian Crystalline Shield (Belebtsev et al., 1995; Verkhovtsev et al., 2014, 2018; Bakarzhiev and Lysenko, 2018) and presented in the National Atlas of Ukraine, 2007 (Rudenko *Ed*). In terms of uranium resources and proven reserves, Ukraine is among the top ten countries in the world and is a leader in Europe. A major share of deposits has insignificant uranium reserves, ranging from 1 to 5 thousand tons. The deposits are characterized by the complexity of tectonic structure and ore bodies' morphology. There are a lot of «windows» of ore-free rocks. Uranium concentrations are usually associated with hydrothermal metasomatic processes, discontinuous tectonics, and various exogenous (syngenetic), diagenetic, and epigenetic veins. Many deposits are genetically unique, so the search for their analogues in many cases did not lead to expected results. However, recent studies have significantly expanded the database of the Ukrainian uranium (thorium) deposits and manifestations (Mikhailichenko, 2018).

Sources of radiation exposure to the environment due to uranium mining are diverse and covered in many publications (Shumlyanskyi et al., 2003; Lyashenko et al., 2011, 2018; Dudar et al., 2015, 2018; Stankevich et al., 2016, 2018) and generalized in the IAEA publication on uranium exploration worldwide (IAEA, 2018). They are aerosol, dust, liquid, solid low-level wastes of mining and ore-processing complexes of uranium deposits and deposits, which are enriched in associated radioactive elements. Environmental components within and beyond areas, where the processes of extraction and processing of radioactive raw materials take place, are subjected to radioactive contamination of various level. Radioactivity caused by uranium ore mining requires special measures to protect the population and the environment in addition to generally accepted control that accompanies the extraction of other metals.

Research methods.

The study uses a comprehensive approach that includes data analysis and generalization on long-term environmental impact due to uranium mining; mineralogical and petrographic analysis of uranium ores and host rocks; method of discriminant functions; mathematical statistics for processing the results of measurements and modeling.

The purpose of the work is to overview and analyze the environmental impact of natural radiation sources within and beyond the uranium mining areas in Ukraine and develop a mathematical model of potential dust air pollution on the example of the oldest uranium mine in highly populated region.

Fig.1 Uranium mining site

Study area. In Ukraine uranium is mined in the vicinity of residential areas in the Kropyvnytskyi district, central Ukrainian uranium province. The territory of the Kropyvnytskyi city and its environs is located in the area within the tectonic node of deep faults that controls uranium mineralization. Natural and man-made factors of radiation hazards have become widespread here (Kalashnik, 2017; Dudar et al., 2019, 2020). The oldest uranium mine Ingulska site located in the south-east part of the city of the city of Kropyvnytskyi is especially worth attention as a unique existing mining area (Fig. 1).

The mine has been developing two remote deposits (Michurinske and Tsentralne) connected under residential neighborhood which is perceived as a source of permanent potential environmental hazard. For half a century since the mine started prospecting, an underground labyrinth was created at depths of 160 to 650 m (Podulyakh, 2017). There are five vertical shafts here and underground tunnel almost 6 km long, passing also under the river Ingul, dug for the connection of both uranium deposits.

After extraction, grinding and radiometric sorting the ore is loaded into the wagons and then transported for further processing to the town of Zhovti Vody, where the hydrometallurgical plant is located. A railway track and automobile roads are connected to the territory of the mine which is also proved to serve as a continuous source of the environmental pollution. Poor off-balance ore and barren rock are stored near the mine in waste rock dumps.

Analysis of uranium content in the environment components. Uranium content in the environment components is a very specific feature of the study area which stipulates its enhanced level of background radiation and development of technogenically enhanced sources of natural origin. Uranium in *rocks* of the earth's crust: 1) is available in mineral form (uranium minerals: uranium black, uraninite, nasturan, cofinite); 2) isomorphically included in the crystal lattices of highly radioactive non-uranium minerals (zircon, monazite, apatite, sphene); 3) is scattered in rocks or dissolved in water. The average uranium content in acid rocks $(1\text{-}6)\cdot10^{-4}\%$), in alkaline – up to $30\cdot10^{-4}\%$ (Shumlyanskyi et. al., 2003; Fomin et al., 2019). Compared with uranium clark in acidic igneous rocks, the average uranium content in the host rocks of the Michurinske ore field is 1.5-2 times higher (table 1).

The uranium content in *soils* varies between $(0.5\text{-}2.1)\cdot10^{-4}\%$. The background is $1\text{-}1.5\cdot 10^{-4}\%$. Uranium scattering halo (uranium content is more than $1.5\cdot10^{-4}\%$) is observed at the Michurinske deposit site. Capillary-diffusion rise of uranium-bearing waters, activated in fault zones, is the cause of the formation of uranium salt halos in the soils, as well as anomalies of radioactivity (at the level of 1 m from the earth's surface).

m from the riverbed. The relief is lowered down from the absolute mark of +140 m on the eastern border of the mining site to +100 m (water inlet of the river Ingul). It means that the uranium salt halo is directed to the riverbed and covers a small area within the mining zone. This fact makes it possible to form surface runoff enriched in natural radionuclides of precipitation and meltwater infiltrated through dumps, as well as from highways and land terrain (Koshik et al., 2013; Dudar et al., 2011, 2015; Sushchuk and Verkhovtsev, 2019).

Availability of fracture zones and their density in host crystalline rocks (granites and gneisses), the presence or absence of uranium minerals, sulfides, iron minerals as well as penetration of gaseous fluids from the earth crust interiors influence on the conditions for radionuclides migration (shumlyanskyi et al., 2007; Fomin et al., 2019; Dudar et al., 2019, 2020). Vertical hydrogeochemical zoning has also been proved due to natural groundwater contamination with uranium, radium and radon. In the upper parts of geological cross-sections, where oxidative conditions prevail, groundwater is maximally saturated with uranium and minimally with radium.

Radon halos tend to fractured zones – faults, the so-called «emanating collectors». The amount of uranium increases in fractured waters. Within zones of weathering crust development, especially in rocks with high uranium content, its concentration in fractured waters increases on average to $70 \bullet 10^{-6}$, reaching $(150\text{-}300) \bullet 10^{-6}$ g/l. That means, it increases 6-25 times compared to the content in waters of Quaternary sediments (Shumlyanskyi et al., 2003, 2007).

Table 1. Average content of uranium in crystalline rocks of the Michurinske ore field

№№	Roks	Samples-number	Uranium content, %
1	Gneiss fine-grained	46	0.0005
2	Gneiss coarse-grained	33	0.0007
3	Gneiss even-grained	15	0.0008
4	Trachytoid granite	42	0.0009
5	Pegmatite	23	0.0008

Availability of radioactive hydrochemical halos in *ground and surface waters* around uranium deposits is another characteristic feature of the study area. All aquifers of the area are fed by precipitation. The main aquifer that feeds the rivers is the one in fractured zone of the Precambrian crystalline rocks. Previous research proved the stability of radioactive hydrochemical halos: the content of radionuclides of uranium, radium and radon is stable over time (Sushchuk and Verkhovtsev, 2019; Fomin, 2019). So, there is a natural contamination of groundwater with radioactive elements. Beyond the ore deposit sites, contamination of uranium surface water is predominant.

The migration of natural radionuclides within the study area and beyond depends on general geomorphological and geochemical conditions. The mining site along with the wastes dumps is located on the left bank of the river Ingul at a distance of 150-200

The concentration of ^{222}Rn in the indoor air is a very specific characteristic feature of the study region residential areas. In particular, it depends on the content of ^{238}U, ^{226}Ra and other radioactive components in the natural environment components - rocks, weathering crust of parent material, soils and groundwater, on ^{222}Rn emanation coefficient from the soil, on the soil properties and condition, on concentration of uranium anomalous in the earth crust. Geospatial analysis of radon-prone areas identification taking into account uranium content in the environment as well as spatial density of faults and lineaments can be of great help for potential radon hazard sites study (Dudar et al., 2019, 2020). Radon-prone areas are considered in the EU Basic Safety Standards (EC Council Directive 2013/59/Euratom, 2014) and of great attention in the European Atlas of Natural Radiation (EU Joint Research Center, 2019).

Research material and discussions.

The uranium ores within the Michurinske ore field are mainly one-component and monomineral in composition. The presence of thorium and other radioactive elements is negligible (table 2.)

All the waste dumps of the Ingulska mine contain a low level of uranium (more than 0.01%). The content of uranium in the dust fraction exceeds the content of uranium in the total samples. The most radioactive are the samples from the foot of almost all waste dumps. The usual uranium content in the dust fraction (<0.25 mm) is 0.01-0.06%. (Shumlyanskyi et al., 2003; Lyashenko et al., 2011; Kovalenko, 2013).

Having analyzed the factors influencing the potential threat of air dust pollution within and beyond the sanitary protection zone (SPZ) of any mining site, it is possible to identify potentially hazardous conditions for any study area and predict measures to eliminate it, especially for residential areas. The authors have analyzed a number of man-made and climatic factors that should be first considered to tackle the task (tables 3, 4).

Of course, in any case, the characteristics of the waste dumps themselves are important - their area, mineral and chemical composition of the crushed rock substrate (which in principle corresponds to the composition of rocks that after a series of underground explosions were crushed and removed to the surface), dust fraction (< 0.25 mm) and the content of uranium in it, which is carried by the wind according to the wind direction. It is also important to take into account the availability of residential areas and the distance to them from the SPZ of the mining site, and to analyze the wind rose and wind speed of the study area in general and on the example of a particular season (and / or year).

The presented study analyzed the potential threat of air dust pollution within and beyond the area of long-term operation of the Ingulska mine on the example of the wind rose of summer 2019. A total of 16 factors for 27 predicted situations were considered and analyzed. All situations were divided into 2 groups: group 1 - with a low level of potential dustiness threat; group 2 - with a high level of potential dustiness threat. The waste dumps area was calculated using the Sentunel-2 images data (as of 07.02.2019) and accurate terrain SRTM (2000) data, presented on the figure 2. It makes up 0.2650 km^2.

To reduce the potential air dustiness threat, the variants of reducing the waste dumps area by at least 2 times are being considered. The uranium content in the dumps dusty fraction is given based on published analyses results (Shumlyanskyi et al., 2003). Climatic data were taken from the World Weather site data (World Weather, 2019). The south-eastern and eastern wind directions (SE+E) are considered to be the most potentially threatening, as in this case the dustiness threatens the south-eastern and eastern outskirts of the city of Kropyvnytskyi located at a distance of 1.5 km to 5 km from the mine waste dumps.

Table 2. Geochemical characterization of the Michrinske uranium deposit [Fomin, 2020]

Chemical elements	U	Th	V	Ni	Pb	Sr	Be	Zr
Content, g/t	5-1670	0.5-4.3	12-54	4.0-12.0	5-810	36-161	1-46	22-291

Table 3. Technogenic and man-made factors influencing the potential dustiness threat

Threat level	Technogenic and man-made factors									
	within SPZ (mining site)						residential sites			
	Waste rock dump area, m^2		U in dusty fraction of waste rock, %		Fraction ≥ 0.25 in samples from dumps, %		Distance from SPZ, km		dose rate at height of 1 м, mkSv/g	
	A	A^1	B	B^1	C	C^1	D	D^1	E	E^1
1	130 000- 160 000	1	< 0.005	1	< 5	1	**>5**	1	0.08-0.09	1
1	161 000-190 000	2	0.005-0.01	2	5-9	2	3,1-5	2	0.10-0.11	2
2	191 000-265 000	3	0.02-0.03	3	10-14	3	2,1-3	3	0.12-0.13	3
2	≥265 000	4	0.04-0.06	4	> 15	4	1-2	4	>0.13	4

Table 4. Climatic factors influencing the potential dustiness threat

Climatic factors																			
NW		N		NE		NE+E		S		SW		W		Wind speed, m/s				Precipitation	
F	F^1	G	G^1	H	H^1	I	I^1	J	J^1	L	L^1	M	M^1	N	N^1	O^1	O^1	P	P^1
11-9	1	11-9	1	11-9	1	<2	1	<2	1	11-9	1	11-9	1	≤ 2	1	30-22	1	14-9	1
8-5	2	8-5	2	8-5	2	4-2	2	4-2	2	8-5	2	8-5	2	4-3	2	21-14	2	8-5	2
4-2	3	4-2	3	4-2	3	8-5	3	8-5	3	4-2	3	4-2	3	6-5	3	13-6	3	5-2	3
<2	4	<2	4	<2	4	11-9	4	11-9	4	<2	0	<2	0	≥ 6	4	<5	4	<2	4

The method of discriminant functions was used to objectify the determination of potential dustiness threat level. This method has a number of advantages: takes into account the variability of the model parameters; considers the signs as a whole and identifies the most significant of them; demonstrates the share of each sign in the final conclusion. Before the discriminant analysis, all signs were coded (tables 3 and 4) and put in accordance with the 16-dimensional vector, which takes into account the absence, presence, focus and magnitude of each sign.

One-factor analysis of variance was used to assess the informativeness level of the model parameters, for which the null hypothesis of no influence was put forward and evaluated. At the same time, an alternative hypothesis was put forward that the influence of the studied sign exists. In order to test the hypothesis, Fisher's criterion (F) was calculated. Observed value of Fisher-test (F_o) was compared with Critical F-value (F_c), which depended on the level of significance p (<0.05). If $F_o > F_c$, then an alternative hypothesis was accepted, which allowed to assert with a probability of at least 0.95 about the influence of the studied sign on the prediction outputs. As a result, three statistically significant and non-correlated signs were identified, which allowed determining the level of potential dustiness threat (table 5).

These signs were further used as the main ones in the construction of the «decision rule» of the mathematical model for predicting the level of potential dustiness threat in the form of equations:

$$F_1(X) = 13.989*X_1-10.018*X_2+10.514*X_3-8.640,$$

$$F_2(X) = 43.502*X_1 - 35.830*X_2 +33.664*X_3-64.748,$$

where X_1 - waste rock dumps area

X_2 - U in dusty fraction of waste rock

X_3 – wind direction – south-eastern and/or eastern

The obtained values of the variables F1 (X) and F2 (X) are compared with each other and under the condition of F_1 (X)> F_2 (X) we can talk about a low level of potential dustiness threat.

The obtained coefficients and constants of discriminant equations reflect a linear regression set of relevant indicators that have the greatest impact on predicting the potential dustiness threat.

Based on the obtained value of discriminant functions, graphs of distribution of values F_1(X) and F_2 (X) were made up (Fig.3), where *a)* graph for group 1, *b)* graph for group 2.

The assessment of optimal assignment likelihood into groups, the usefulness of discriminant functions and the number of functions that have real meaning in determining the differences between groups were evaluated using canonical correlation coefficients. Having analyzed the obtained value of the canonical correlation coefficient (0.965), one can draw the following conclusion. There is a high positive relationship between the real process and the predicted values obtained through mathematical model, which is also confirmed by the high percentage of absorbing dispersion of this function (99.0%) .

The assessment of the discriminant functions significance was verified by Wilkes λ-statistics (table 6), according to the formula:

$$, \quad \lambda_i^* = \prod_{i=k+1}^{g} \frac{1}{1+\lambda_i} \qquad (1)$$

where k is the number of calculated functions; λ_i is the eigenvalue.

Table 6. Significance of discriminant functions

Test of Function (s)	Wilks' Lambda	df	Sign.
1 to 2	0.069	3	0.001

The λ-Wilkes test showed that the level of differences is quite significant (p = 0.001).

The accuracy of classification, according to the obtained model, is estimated on the basis of comparison of coincidences of the predicted and actual groups and presented in table 7.

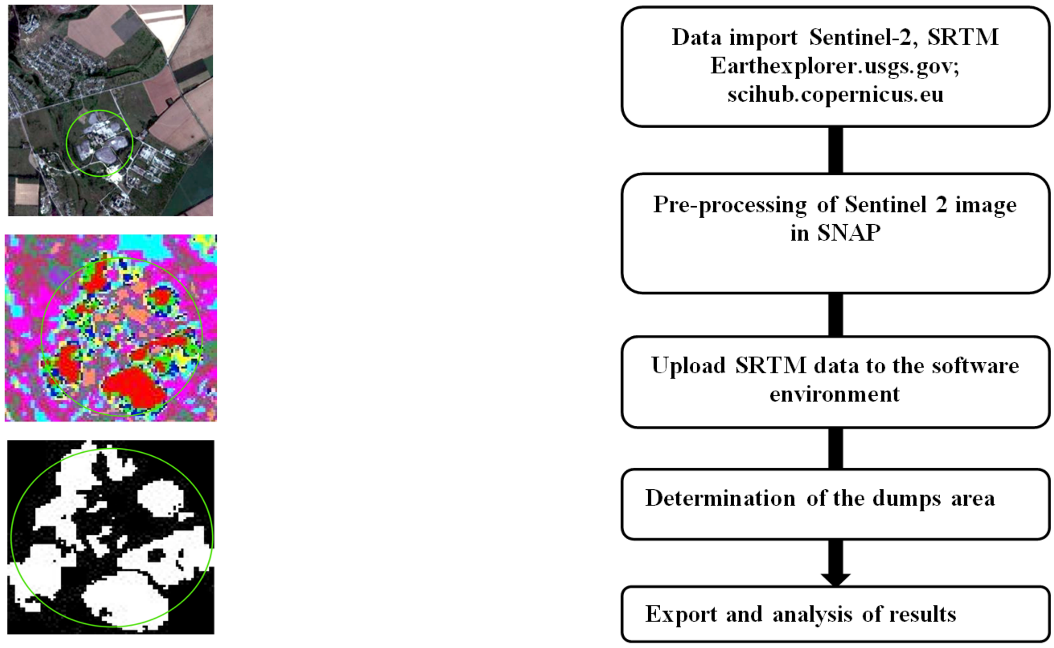

Fig. 2 Chain for waste dumps area determination

Table 5. Results from the estimation of the model parameters informativeness

Predictors included in the model	Observed F-value	Significance
Wind direction SE+E	141.667	0.001
Waste rock dumps area, m^2	95.368	0.009
U in dusty fraction of waste rock, %	104.212	0.001

Table 7. Classification accuracy

Pollution hazard	Predicted Group Membership		Total
	Group 1	Group 2	
Group 1	17	0	17
Group 2	1	9	10

Thus, the developed mathematical model allows correctly determining the level of potential dustiness threat in 96.3% ± 3.6% of all cases.

Conclusions.

Studies of unique waste rock dumps of uranium mining in the Kirovohrad uranium ore subprovince allowed identifying them as sources of potential dustiness threat in the surface layers of atmospheric air with fine dust (less than 0.25 mm) containing uranium, its decay products and associated elements. Uranium mining dumps serve as a source of radioactive pollution of the environment, including residential areas. Uranium accumulates in the dusty fraction, where its content is 0.01-0.06%. Taking into account

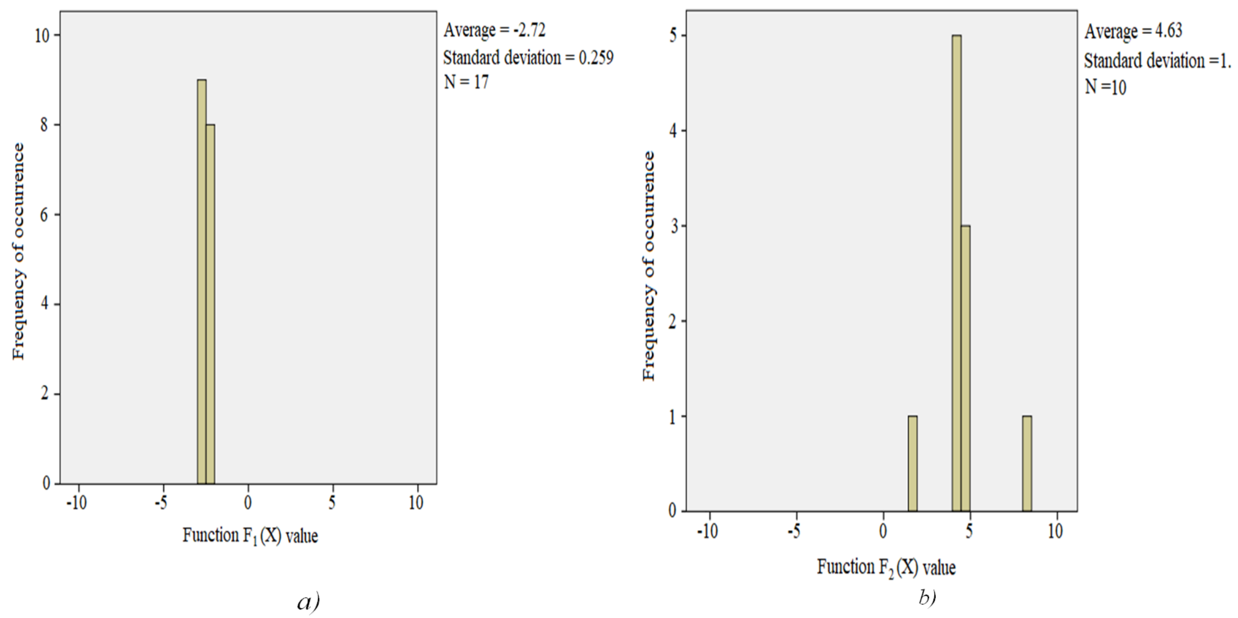

Fig. 3. Distribution of the discriminant function values›: a*)* group 1; *b*) group 2

the geological and geochemical characteristics of uranium deposits, radioactive elements, heavy metals and other associated elements of uranium mineralization are carried out of dumps by winds and atmospheric waters with their subsequent migration into the environmental components.

The results of comprehensive research have identified the main ways for prediction the potential dustiness threat in the vicinity and beyond mining site of the Ingulska mine. The developed mathematical model based on the method of discriminant functions, taking into account the area of waste rock dumps, uranium content in the dust fraction and wind direction southeast and /or east, allows correctly determining the level of potential dustiness threat in 96.3% ± 3.6% of all cases for the south-eastern and eastern outskirts of the city of Kropyvnytskyi.

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Using Geo-electric Techniques for Vulnerability and Groundwater Potential Analysis of Aquifers in Nnewi, South Eastern Nigeria

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Abstract. In Nnewi, Anambra State Nigeria, twenty vertical electrical sounding (VES) were performed to delineate vulnerability and transmissivity of identified aquifer within the study area. Hydraulic parameters (transverse resistance, longitudinal conductivity, hydraulic conductivity and transmissivity) were delineated from geoelectrical parameters (depth, thickness, and apparent resistance). The geo- parameters of the aquifer: apparent resistance from 1000.590 to 1914.480, thickness from 42.850 – 66.490 m and 65.530 to 100.400 m of depth. The estimated hydraulic parameters of the aquifers are transverse resistance 54264.383 - 104568.898 Ωm, longitudinal conductance 0.029 – 0.062 mho, hydraulic conductivity 0.664 – 2.015 m/day and transmissivity between 4.167 and 13.963 m^2/day. All aquifers have poor protective capacity, 40 percent of the aquifers have low classification with smaller withdrawal potential for local groundwater supply, while 60 percent of the delineated aquifer has intermediate classification and withdrawal potential for local groundwater supply. Due to its groundwater supply potential and protective capacity, the eastern part of the study area has stronger groundwater potential.

Keywords: Hydraulic Conductivity, Transmissivity, Transverse Resistance, Longitudinal Conductance

Використання геоелектричних методів з метою аналізу вразливості та потенціалу запасів підземних вод потенційно водоносних горизонтів у місті Неві Південно-Східної Нігерії

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Анотація. У Неві (штаті Анамбра в Нігерії), було проведено двадцять вертикальних електричних зондувань (ВЕЗ), для того щоб довести вразливість та проникність ідентифікованого водоносного горизонту у досліджуваній області. Гідравлічні параметри (поперечний опір, поздовжня електропровідність, гідравлічна провідність і проникність) були відмежовані від геоелектричних параметрів (глибини, товщини та видимого опору). Геопараметри водоносного шару: явний питомий опір від 1000.590 до 1914.480, товщина від 42. 850 - 66.490 м та глибина від 65.530 до 100.400 м. Розрахункові гідравлічні параметри водоносних горизонтів - поперечний опір 54264.383 - 104568.898 Ом, поздовжня електропровідність 0,029 - 0,062 См гідропровідність 0,664 - 2,015 м / добу і прохідність між 4,167 до 13,963 $м^2$ / добу. Усі водоносні горизонти мають низьку захисну здатність, 40 відсотків водоносних горизонтів мають низьку класифікацію із меншим потенціалом вилучення місцевих джерел ґрунтових вод, тоді як 60 відсотків відмежованого водоносного горизонту має проміжну класифікацію та потенціал вилучення місцевих підземних вод. Через свій потенціал подачі підземних вод та захисну здатність східна частина досліджуваної території має більш високий потенціал підземних вод.

Ключові слова: гідропровідність, проникність, поперечний опір, поздовжня провідність

Introduction.

Water is the most important necessity nature provides for flora and fauna to survive and thrive, and it also plays a monumental role in every mode of human life (Nwankwoala and Nwagbogwu, 2012). Hence, usable water quality is a significant metric of man's quality of living (Elueze, et al., 2004). Nonetheless, water quality is influenced by the features of the circulation and occurrence system. Typically, these sources are exposed to anthropogenic and industrial contaminants (Egbunike and Okpoko, 2018). Despite its importance, water is the planet's most undermanaged resource (Fakayode, 2005). The current urbanization and industrialization trend can contribute significantly to poor water quality through extrajudicial discharge of solid waste, industrial waste, or other hazardous waste. (Ugochukwu, year 2004).

Water is one of the important supporters of all aspects of living organism life (Vanloon and Duffy, 2005). It is usually collected from two key natural sources; surface water such as lakes, rivers and streams; and groundwater such as wells drilled by borehole and by hand (McMurray and Fay, 2004; Agbasi and Etuk 2016). Because of its hydrogen bonds, water has peculiar chemical composition which allows it to dissolve, engulf or suspend into many different compounds (WHO, 2007). Water is not pure in nature because it inherits toxins from its climate and those from humans and livestock, as well as from other ecological activities (Agbasi and Etuk 2016).

Groundwater, for more than half of the world's population, happens to be a far more sustainable source of water (Alabi et al., 2010; Anomohanran, 2013), and is described as that part of precipitation that enters the ground and percolates downward through unconsolidated materials and openings in bedrock until it reaches the water table. This unconsolidated soil, which can produce water in accessible amounts, is known as aquifer (Alabi et al., 2010). Aquifer properties which are known to influence the accessibility of groundwater involve aquifer thickness and the size and magnitude of pore space connectivity within the aquifer. These properties affect the ability of an aquifer to store and transmit groundwater (Ochuko, 2013). These approaches involve electrical resistivity, gravitational, gravity, magnetic and magnetulluric seismic refraction (Karani et al., 2009; Majumdar and Das, 2011; Todd, 2004). Method selection primarily relies on the depth of inquiry, and often the expense (Todd, 2004) of all such methods used in groundwater research has become the most commonly used method of electrical resistivity profiling. This is because its ionic content is immune to the resistance of rocks (Alile et al., 2011And the device's operation is unfussy, and data processing is economical (Ezeh and Ugwu, 2010; Anomohanram, 2011; Atakpo and Ofomola, 2012). The method of electric resistivity is used to estimate the depth of the bedrock surfaces and the thickness of the soil or rock (Nwankwo, 2011). The approach is also used for studying groundwater pollutants and their patterns of movement (Ehirim and Ofor, 2011).

Vertical electrical sounding (VES) has been shown to be efficient in most areas of Nigeria in resolving groundwater problems (Onuoha and Mbazi, 1988; Mbonu et al., 1991; Mbipom et al., 1996; Ekine and Osobonye, 1996; Eze and Ugwu, 2010; Namdie and Idara 2017). In the present study, an attempt had been made to establish the aquifer characteristics in the study area, an estimated the hydro-geophysical parameters of the aquifer to delineate their vulnerability for human usage.

Hydrogeology of the study area.

Anambra State occurs primarily within the Niger Delta Region, with the exception of the far southeastern portion apex of the state that is underlain by a section of Anambra Region. The geological origins of Anambra and Niger Delta Basins was exquisitely related to the mega-tectonic structural pattern correlated with the breakup of the Gondwanaland during the Late Jurassic to Early Cretaceous (Onuigbo et al., 2015). The Anambra Basin is theorized to have formed contemporaneously with the folding of the Benue Trough in the Santonian due to the depression of the region around the southern Benue Trough. Syngenetically, the Niger Delta Basin developed as a continuous subsidence of the Southern Benue Trough and Anambra Basin, as defined by the rupture zones of Chain, Charcot and Romanche. The Cenozoic Niger Delta is therefore superimposed on the Benue Trough and Anambra Basin in the south (Nwajide, 2013).

The Ameki Group's components are the Ameki, Nanka, and Nsugbe Formations that overlie the Imo shale group in conformity. Ameki Group's facie is underpinned by more than 35 percent of Anambra Province. Ameki and Nanka Formation lithofacies are loose, flaser-bedded, fine-medium-grained sand with very few mudrockbreaks (Nwajide, 1979).

Two formations underlie the study area; Eocene Nanka Sands Formations (Ameki group) and Quaternary Ogwashi-Asaba Formation (Nwajide, 2013). The Nanka Sands, Nnobi, Ojoto and some pieces of Nnewi underlie that. It is a sequence of lowly accumulated, poorly sorted, friable, medium

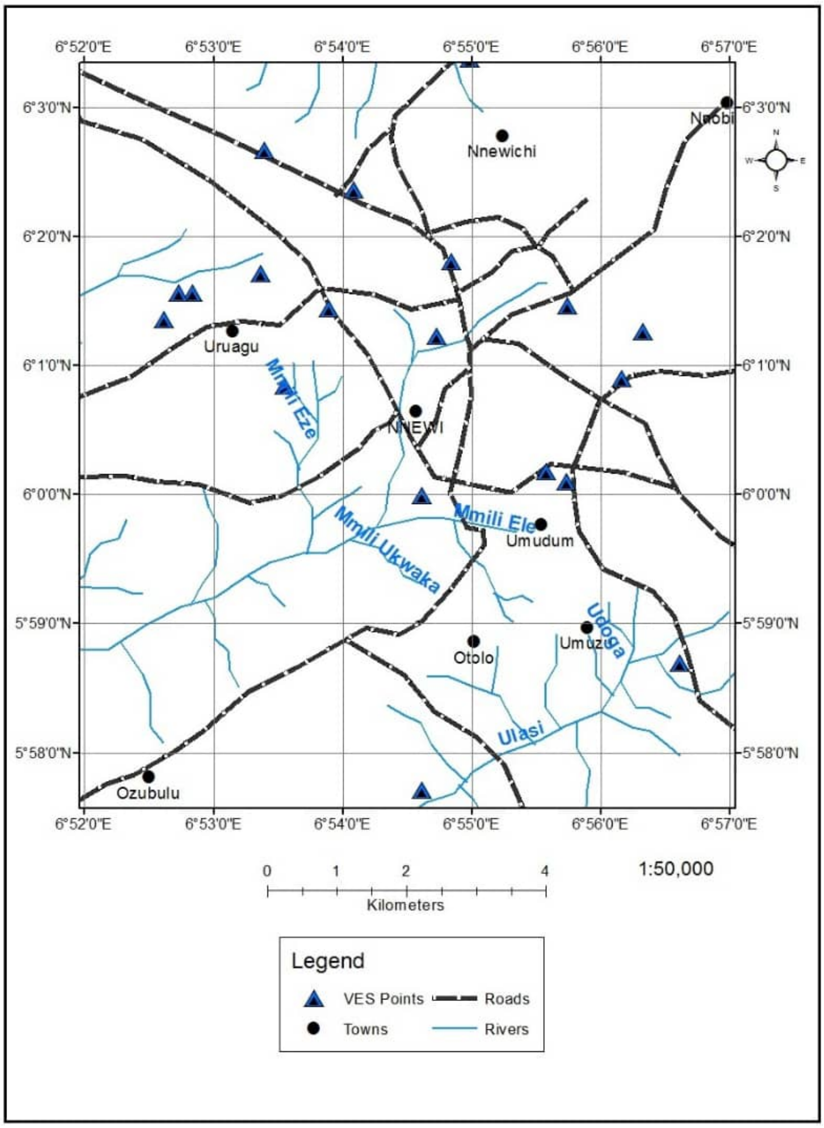

Fig. 1: Map of the study area showing the VES points

to coarse Eocene age sands in the study region. The formation includes thin clay stone, siltstone, and shale bands. The units have strong permeability and porosity. The aquiferous sandstone unit is (Nwajide, 1979). The Ogwashi-Asaba Formation overhangs the Nanka Sands, this consists of the lignite and clay intercalations.

Nanka Sands underlines the upper parts of the study region which are Nnewichi, Nnewi, these have unconsolidated color, loose and cool, white to brownish sand. (Onu, 2017).

In the study region, the presence of several streams and rivers indicates rapid percolation of rainwater through the soil. This is also due to the extremely porous and permeable soil character. Nanka Sand is very aquiferous and this accounts for the many water boreholes that have been drilled into the site.

The aquifer depth in the region ranges from 134 m to 237 m below the ground. Water levels occur in the plains and river courses at shallow depths, and in the highlands at greater depths. Groundwater in the field of research is recovered through rainfall absorption and surface runoff. The cost of deep aquifer extraction is high among the study area residents with the associated risk of drilling abortive boreholes because most of the time there were no professionals involved in exploration (Obeta, 2015).

Methodology.

Geophysical electrical resistivity studies describe a subsurface medium consisting of layers of materials with different resistivities, assuming all the layers are horizontal.

A material resistivity ρ is a function quantifying how much the material retards electrical current flow. The resistivity differs greatly from one substance to the next, because of this great variety, calculating the resistivity of an unknown substance, provided no more detail, has the potential to be very useful in identifying the substance. Throughout field studies a material resistivity can be combined with reasoning along geological lines to classify the materials that make up the different underground layers.

The amount of water recharging an unconfined aquifer is calculated by:

- the amount of precipitation that is not lost by evapotranspiration and runoff and is therefore available for recharge;
- the vertical hydraulic conductivity of surface deposits and other strata in the aquifer recharge region, which determines the volume of recharged water capable of moving down.

Should an aquifer transfer the full amount of water, any possible regeneration in the recovery region is more than likely rejected. In humid areas (as in the study area) this is always the case. Unless the water level below shows that the aquifer may not flow at maximum capacity, the recharge region is possibly either deficient in possible recharge or poor vertical hydraulic conductivity, retarding downward motion (Fetter Jr., 2014).

The relationship between hydraulic parameters and geo-electric parameters is strongly influenced by the aquifer substratum composition (Agbasi, et al., 2019; Harry et al., 2018). In a standard unit column of the aquifer, both current and the hydraulic flows are prevalently horizontal for an extremely resistive substratum, and the correlation between hydraulic conductivity (K) and apparent resistivity (ρ) is inverse. If the substratum is strongly penetrable, the hydraulic flow would still be vertical, while the present flow is prevalently vertical in a characteristic unit column. Therefore, there is a clear correlation between K and ρ. If the aquifer material is sliced from top to bottom in the shape of a vertical prism of the unit cross-section, fluid flow and current flow in the aquifer substance simultaneously follows Darcy's law and Ohm's law. Thus, the transmissivity of the aquifer is described as: for current and fluid flows in a directional manner:

$$T = \sum_{i=1} K\rho S = \sum_{i=1} Kh \quad (1)$$

where ρ is the bulk resistivity and

$$S = \sum_{i=1} \frac{h}{\rho} \quad (2)$$

S is the longitudinal unit conductivity of the aquifer material with thickness *h*.

For a lateral hydraulic flow and current flowing transversely, the transmissivity of the aquifer becomes

$$T = \sum_{i=1} \left(\frac{K}{\rho}\right) R = \sum_{i=1} Kh \quad (3)$$

where ρ is the bulk resistivity and

$$T = \sum_{i=1} \left(\frac{K}{\rho}\right) R \quad (4)$$

where R is the transverse unit resistance of the aquifer material

For hydraulic conductivity K, we have

$$K = 8 \times 10^{-6} e^{-0.0013\rho} \quad (5)$$

Then

$$T = (8 \times 10^{-6} e^{-0.0013\rho})h \quad (6)$$

If the aquifer is saturated with water with uniform resistivity, then the product $K\rho$ or K/ρ would remain constant. Thus, the transmissivity of an aquifer is proportional to the longitudinal conductivity for a highly resistive basement where electrical current tends to flow horizontally, and proportional to the transverse resistance for a highly conductive basement where electrical current tends to flow vertically (Umoren, et al., 2017). The above equations may therefore be written as:

$$\rho^2 = \sum_{i=1} \frac{S}{R} \quad (7)$$

The model resistivity values derived from the inversion method were used from these relations to evaluate the aquifer unit longitudinal unit conductance and transverse unit resistance.

Considering that most minerals have high electrical resistivity (outlier: saturated clay, metal ores, and graphite), the electrical current flows primarily via the pore water.

The major equipment used in the field is the ABEM SAS 1000 Terrameter. Other accessories used for the field work are measuring tape (for taking distance measurement), Global Positioning System (for determining the location and elevation of sampling points), battery (12V used to power the Terrameter), electrodes (a total of four electrodes were used), and hammers (are used to drive the electrodes into the ground to ensure good contact).

Results.

Twenty vertical electrical sounding, conducted in Nnewi, Anambra state. Figure 2 show the interpretation of the VES data. In the twenty VES stations six (6) geoelectric layers have been identified. The form of a curve within the study area is shown in the Table 1.

The top soil resistivity is between 759.56 – 3308.18 Ωm with a thickness varying from 1.94 – 9.12 m. The second geoelectric layer consists of a lateral shale with a thickness of 1.68 – 30.75 m and apparent values of resistivity varying from 539.15 to 2330.89 Ωm. The third geoelectric layer is superficial

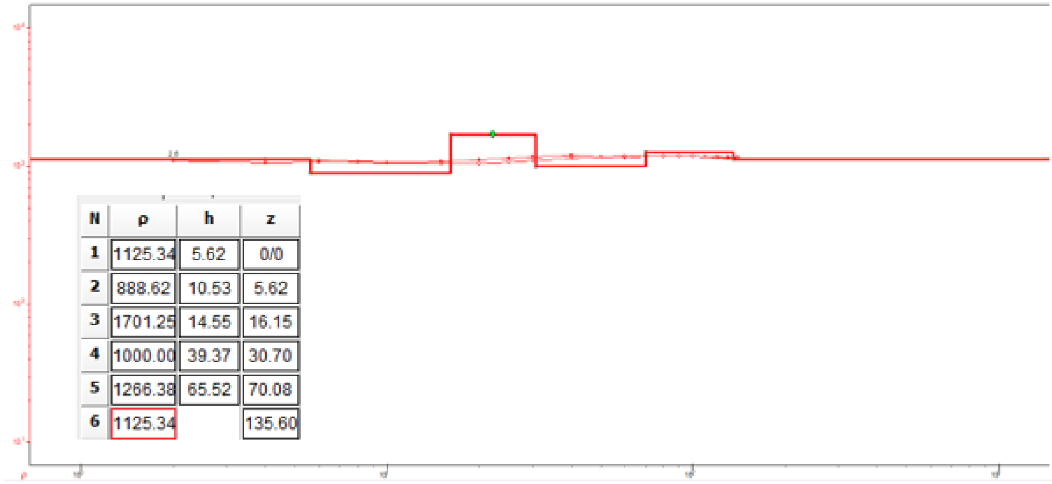

Fig. 2: A fragment of a computer iterated analysis based on a VES station

in nature with an apparent layer of resistivity of 750.74 to 2240.93 Ωm with a thickness of 14.23 to 29.30 m. The fourth geoelectric layer is the sandstone layer, between 835.60 and 1804.72 Ωm the range of apparent resistivity. The aquifer layer is identified in the fifth geoelectric layer, they have an apparent resistivity value between 1060.82 – 1914.48Ωm with thickness of 51.28 – 66.49m across the twenty (20) VES stations in the study area.

The Figure 3 displays a 2D contour map and 3D surface of apparent resistivity variance in the aquifer across the study area. The central parts of the area have moderate apparent resistance values compared to other parts, and the northwest part of the study area also shows an increasing value of apparent resistance.

Table 1. Curve type of the various VES stations

VES	Curve Type
1	HH
2	AQ
3	QH
4	KQ
5	HQ
6	AH
7	KH
8	QH
9	HA
10	QK
11	QA
12	HA
13	KK
14	AH
15	HH
16	HK
17	KK
18	QH
19	KK
20	KK

Figure 4 shows the 2D contour map and 3D surface of the aquifer thickness in the study area. The south-western part has the highest aquifer thickness, with the majority of the VES station in the eastern part of the study area having a moderate thickness.

Figure 5 shows the 2D contour map and 3d surface of the longitudinal conductivity across the aquifers in the study area. The majority of the study area of moderate longitudinal conductivity is expected to have high longitudinal conductivity values for the northwest parts of the region.

The 2D contour map and 3D surface of hydraulic conductivity (Fig. 6) shows a pattern of increasing from the west to the eastern, with the lowest values found around the northwest parts of the study area.

The Figure 7 with the 2D contour map and 3D surface of the transmissivity shows higher values in the eastern and northern portions of the study area compared to the western southern and northern parts.

The Table 2, shows the aquifer geoelectric and hydraulic parameters calculated in the study area, a standard table (tables 3 and 4) were used to infer the hydraulic parameters of the aquifers, which is presented in the Table 5. All the aquifers in the study area have poor protective aquifer. 40% of the aquifers in the study area have low designation and smaller withdrawal for the local water supply (private consumption), while the other 60% have Intermediate and Withdrawal of local water supply (Small community, etc.) for designation and groundwater supply potential respectively.

Longitudinal conductivity and the study area transverse resistance were also measured using geoelectric parameters of the aquifers. It has been found that most parts of the study region have an

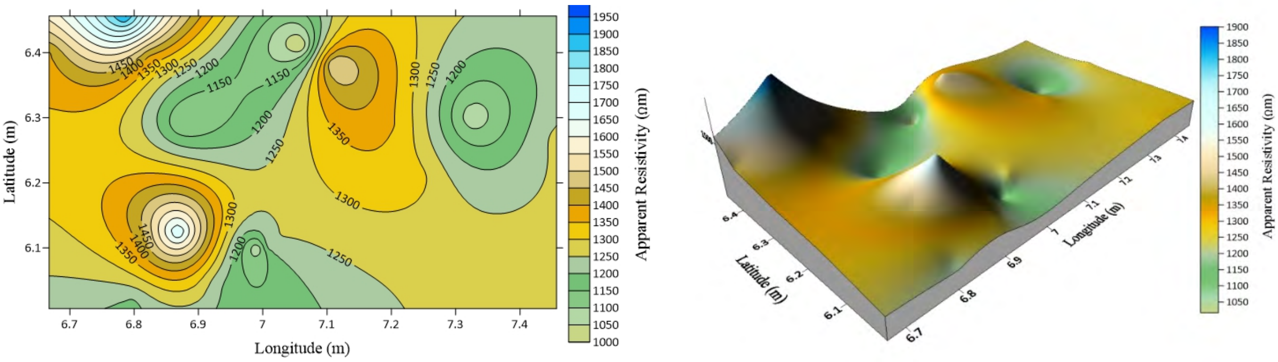

Fig. 3. 2D contour map and 3D surface of apparent resistivity variance in the study area

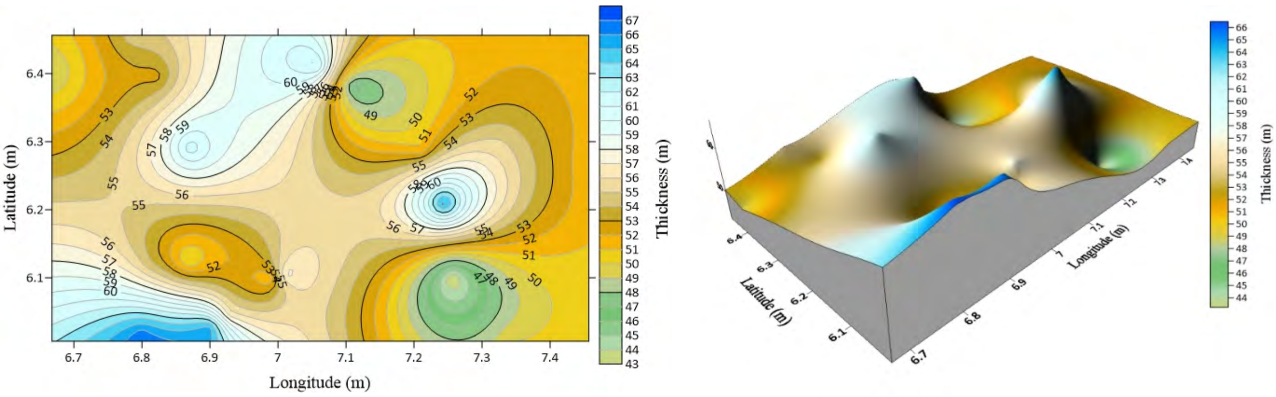

Fig. 4. 2D contour map and 3D surface of the aquifer thickness in the study area

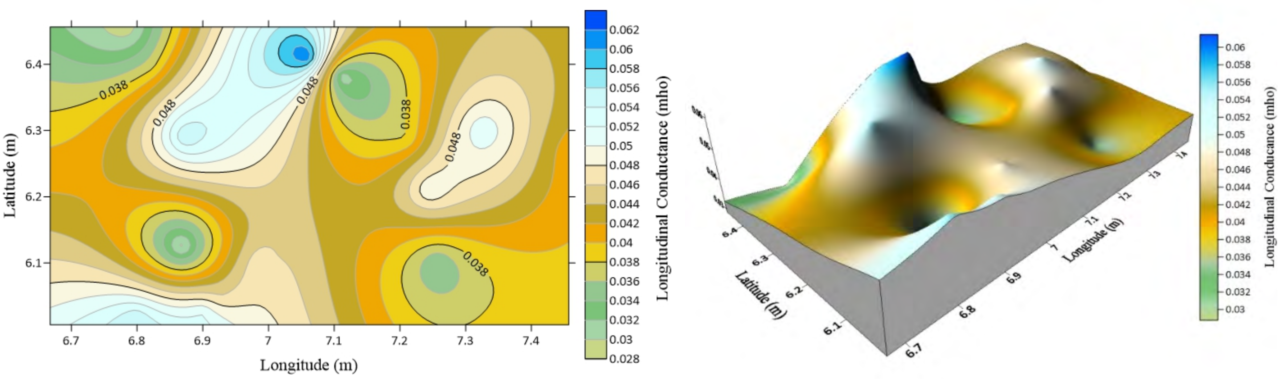

Fig. 5. 2D contour map and 3D surface of longitudinal conductance in the study area

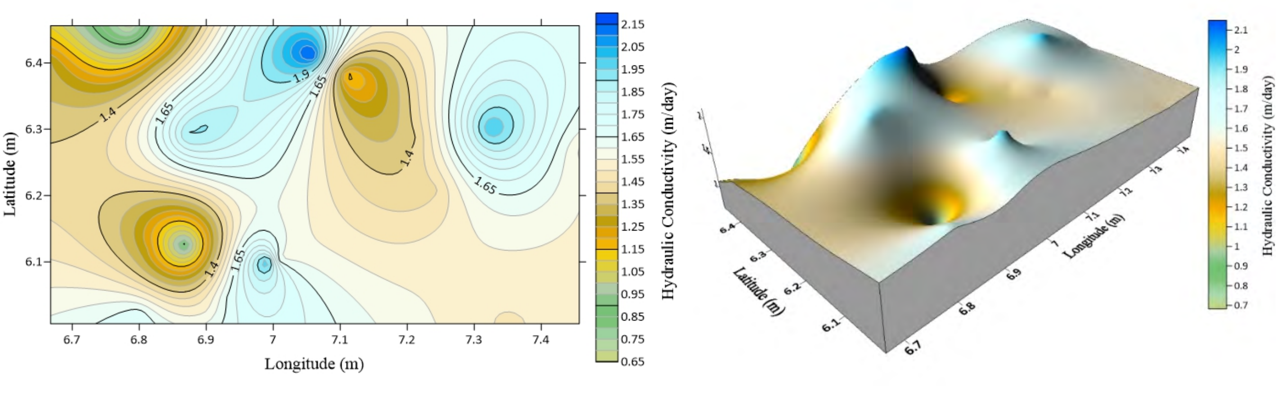

Fig. 6. 2D contour map and 3d surface of hydraulic conductivity in the study area

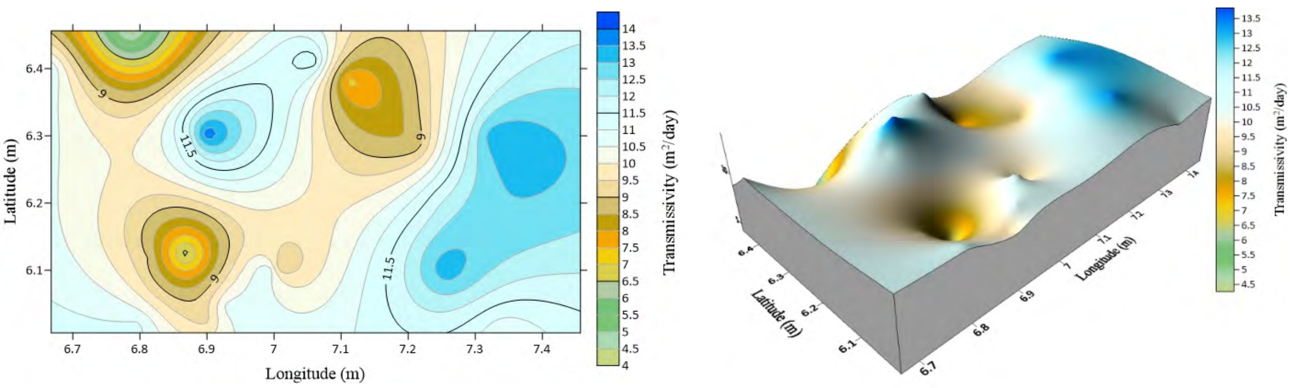

Fig. 7: 2D contour map and 3D surface of transmissivity in the study area

Table 2. Geoelectric and hydraulic properties of the aquifer in the study area

VES	Apparent Resistivity (Ωm)	Thickness (m)	Depth (m)	Transverse Resistance (Ωm²)	Longitudinal Conductivity (mhos)	Hydraulic Conductivity (x 10⁶) (m/day)	Transmissivity (m²/day)
1	1266.380	65.520	70.080	82973.218	0.052	1.542	9.337
2	1193.780	66.490	75.660	79374.432	0.056	1.695	11.079
3	1217.500	56.560	75.100	68861.800	0.046	1.643	10.663
4	1103.410	61.710	69.950	68091.431	0.056	1.906	11.519
5	1060.820	55.110	76.550	58461.790	0.052	2.015	13.324
6	1241.700	57.370	65.530	71236.329	0.046	1.592	9.016
7	1343.400	51.260	71.640	68862.684	0.038	1.395	8.636
8	1060.820	51.260	62.740	54377.633	0.048	2.015	10.920
9	1000.590	62.270	62.740	62306.739	0.062	2.179	11.810
10	1317.220	65.870	94.420	86765.281	0.050	1.443	11.776
11	1914.480	54.620	72.620	104568.898	0.029	0.664	4.167
12	1397.330	52.640	68.710	73555.451	0.038	1.300	7.722
13	1291.550	49.950	81.110	64512.923	0.039	1.492	10.459
14	1704.250	49.890	82.810	85025.033	0.029	0.873	6.244
15	1511.780	46.530	75.550	70343.123	0.031	1.121	7.317
16	1266.380	51.230	96.910	64876.647	0.040	1.542	12.912
17	1397.330	48.930	96.890	68371.357	0.035	1.301	10.889
18	1266.380	42.850	100.400	54264.383	0.034	1.542	13.377
19	1103.410	59.890	84.790	66083.225	0.054	1.906	13.963
20	1425.100	54.370	83.060	77482.687	0.038	1.255	9.003

unprotected aquifer as shown by low longitudinal conductivity values below 0.1. The low longitudinal conductivity across the study area is representative of the high permeability, hydraulic conductivity and low clay volume characterizing the study area. The high transverse resistance values indicate the yield of aquifer units from local water supply between low and intermediate determination of transmissivity and withdrawal.

Conclusion.

Geophysical investigations involving the use of vertical electrical sounding (VES) using the Schlumberger electrode configuration, carried out in the study area, to ascertain hydraulic unit flow and protective capacity of the aquifers. All identified aquifers in the study area have poor protective capacity; therefore, it is necessary for further treatment of groundwater after withdrawal. Also, the study area is likely prone to groundwater contaminations, because it is located in an industrial area with poor drainage facilities. About 60 percent of the investigated aquifer area has intermediate designation and withdrawal potential of local groundwater supply, while 40 percent of aquifer area has low designation and smaller withdrawal potential of local groundwater

Table 3 Standard transmissivity vales for groundwater supply potential (Agbasi and Etuk, 2016)

Transmissivity (m/day)	Designation	Groundwater Supply Potential
1000	Very high	Withdrawal of great regional importance
100 – 1000	High	Withdrawal of lesser regional importance
10 – 100	Intermediate	Withdrawal of local water supply (Small community, plant etc.)
1 – 10	Low	Smaller withdrawal for local water supply (Private consumption)
0.1 – 1	Very low	Withdrawal for local water supply (Private consumption)
< 0.1	Impermeable	Sources for local water supply are difficult

Table 4 Standard longitudinal conductivity value for protective capacity (Agbasi and Etuk, 2016)

Longitudinal Conductivity (mhos)	Protective capacity
> 10	Excellent
5 – 10	Very good
0.7 – 0.49	Good
0.2 – 0.69	Moderate
0.1 – 0.19	Weak
< 0.1	Poor

Table 5. Interpretation of hydraulic parameters of the 20 VES station in the study area

VES	Designation	Groundwater Supply Potential
1	Low	Smaller withdrawal for local water supply (Private consumption)
2	Intermediate	Withdrawal of local water supply (Small community, plant etc.)
3	Intermediate	Withdrawal of local water supply (Small community, plant etc.)
4	Intermediate	Withdrawal of local water supply (Small community, plant etc.)
5	Intermediate	Withdrawal of local water supply (Small community, plant etc.)
6	Low	Smaller withdrawal for local water supply (Private consumption)
7	Low	Smaller withdrawal for local water supply (Private consumption)
8	Intermediate	Withdrawal of local water supply (Small community, plant etc.)
9	Intermediate	Withdrawal of local water supply (Small community, plant etc.)
10	Intermediate	Withdrawal of local water supply (Small community, plant etc.)
11	Low	Smaller withdrawal for local water supply (Private consumption)
12	Low	Smaller withdrawal for local water supply (Private consumption)
13	Intermediate	Withdrawal of local water supply (Small community, plant etc.)
14	Low	Smaller withdrawal for local water supply (Private consumption)
15	Low	Smaller withdrawal for local water supply (Private consumption)
16	Intermediate	Withdrawal of local water supply (Small community, plant etc.)
17	Intermediate	Withdrawal of local water supply (Small community, plant etc.)
18	Intermediate	Withdrawal of local water supply (Small community, plant etc.)
19	Intermediate	Withdrawal of local water supply (Small community, plant etc.)
20	Low	Smaller withdrawal for local water supply (Private consumption)

supply. The evaluated hydraulic flow parameters identified for the study area are highly suitable in groundwater assessments both for industrial and residential purposes.

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New perspective Reza gold deposit (Gedabek ore district, Lesser Caucasus, Azerbaijan)

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Abstract: The article describes Reza gold deposit of Ugur exploration area located in Gedabek Ore District of the Lesser Caucasus in NW of Azerbaijan. It is established that main mineralization in the Reza gold deposit consists of hematite-barite-quartz-kaoline veins-veinlets and breccia, pyrite stock-stockverk and quartz-sulfide veins. On the main orebody surface center secondary quartzites with vein-veinlets barite-hematite mineralization have occured over which remain accumulations of hydrous ferric oxides cementing breccias of quartz and secondary quartzites. "Reddish mass" is also observed in erosion parts, being an oxidation product of stock and stockverk limonite-hematite ores. Representing typical gossans, these accumulations by the data of trenches for thickness about 5-10 m contain gold 0.3-3.5 ppm and silver 1.0-45.0 ppm. There are three zones of gold mineralization within the Reza gold deposit: oxide mineralization; transition zone mineralization; sulfide mineralization. The oxide gold mineralization consists of clay-gravel weathering crust of kaolinite type. The gold-bearing mineralization has been oxidized to a depth of approximately 50-100 meters. Typically, the gold mineralization is coarser and a minor increase in gold grade occurs within the oxides compared to the original rocks. The nugget effect increase in the gold grade of the oxides does not exceed approximately 10%. Deposit alteration signature has characteristics which suggest the current outcrop level may be near the top of a mineralized, gold-bearing high sulfidation epithermal (HSE) system. The gold mineralization at the deposit is interpreted as forming in shallow high sulfidation epithermal systems. The mineralization has been noted in well-confined hydrothermal breccia and associated with pyrite stock-stockwork. The majority of the deposit material and current estimates are formed within the barite-hematite-quartz-kaoline mineralization in the secondary quartzite rocks. The main brecciation and stockwork are hosted within secondary quartzite, sometime massive silicified andesite porphyritic rocks.

Key words: *Reza gold deposit, Gedabek Ore District, Lesser Caucasus, mineral association, gold mineralization, high sulfidation epithermal systems*

Нове перспективне родовище золота Реза (Гедабекскій рудний район, Малий Кавказ, Азербайджан)

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Анотація. У статті описується родовище золота Реза Угурскої розвідувальної ділянки, розташованої в Гедабекском рудному районі Малого Кавказу на північному заході Азербайджану. Встановлено, що основна мінералізація родовища золота Реза представлена гематит-барит-кварц-каоліновими жилами-прожилками і брекчиями, пірітвміщуючими штокверками і кварц-сульфідними жилами. У центрі поверхні основного рудного тіла залягають вторинні кварцити з прожилками барит-гематитової мінералізації, над якими залишаються скупчення водних оксидів заліза, що цементують брекчии кварцу і вторинних кварцитів. А в ерозійних ділянках спостерігається «червона маса», що є продуктом окислення штокверкової і лимонит-гематитової руди. Ці скупчення за даними траншей потужністю близько 5-10 м містять золото 0,3-3,5 промілле і срібло 1,0-45,0 проміле. В межах родовищі виявлені три зони золотого зруденіння: оксидна мінералізація; мінералізація перехідної зони; сульфідна мінералізація. Оксидна мінералізація представлена глинисто-гравійною корою звітрювання каолінітового типу. Золотовмісна мінералізація була окислена до глибини приблизно 50-100 метрів. Зазвичай золота мінералізація більша, і в оксидах відбувається незначне підвищення вмісту золота в порівнянні з вихідними породами. Характеристика зміненої зони родовища вказує на те, що поточний рівень виходу може перебувати поблизу вершини мінералізованої золотоносної епітермальной системи з високим рівнем сульфідизації (ВРС). Мінералізація золота на родовищі інтерпретується як формування в неглибоких високосульфідизованих епітермальних системах. Було відзначено, що мінералізація утворюються в добре обмежених гідротермальних брекчиях і асоціюється в піритових шток-штокверках. Велика частина матеріалу родовища і сучасні оцінки сформовані в межах барит-гематит-кварц-каолінової мінералізації у вторинних кварцитах. Основні брекчії і штокверки знаходяться всередині вторинного кварциту, іноді в масивних силіцітізованих андезитових порфірітових породах.

Ключові слова: золоторудне родовище Реза, Гедабекскій рудний район, Малий Кавказ, мінеральна асоціація, мінералізація золота, високосульфідна епітермальна система

Intoduction.

Gedabek ore district is located in the territory of Shamkir uplift of the Lok-Karabakh island arc volcanic structural-formation zone in the Lesser Caucasus Mega-anticlinorium. The ore region has a complex geological structure, and it has become compl ex with the intrusive masses and breaking structures of different ages and different composition. Lower Bajocian is essentially composed of an uneven succession of diabase and andesite covers, agglomerate tuffs, tuff-gravelites and siltstones. Tuff facies of the Lower Bajocian were exposed to strongly metamorphism (skarn alteration and hornfelsing) as a result of the impact of Upper Bajocian volcanism and intrusives of Upper Jurassic age. Only subvolcanic facie of the Upper Bajocian in the Gedabek mine has been studied (rhyolite and rhyodacite, quartz-porphyry). Rocks related to the Bathonian stage have developed mainly in the northern and southern edges of Shamkir uplift (Abdullaev et al., 1988).

Gedabek ore district and Shamkir uplift in general is complex in terms of its tectonic structure and its magmatism is complex too. Magmatic processes in this region have occurred intensely. There are 3 phases of magmatism in the ore area: 1. Bajocian phases; 2. Bathonian phases; 3. Upper Jurassic phases (Fig. 1).

The Bajocian phase is divided into two autonomous sub-stages:

Lower Bajocian age rocks – intermediate and basic composition pyroclastic volcanic and volcanic disturbed rocks – occupy the central part of Shamkir uplift, and have become complex with intrusive and subvolcanic complexes and breaking structures of different ages, morphology.

Acid composition products of the Upper Bajocian magmatism are represented very broad by all facies within Gedabek ore district. It can be considered that the magmatic centre of the Upper Bajocian period is located in the Shamkir uplift.

Andesite, partially andesite-basalt composition products of the Bathonian phase of magmatism, as well as various composition pyroclastic materials and lava flows Upper Jurassic phase are spread mainly in the sidelines of Shamkir uplift. Along the breaking structures and in the areas between them, rocks along micro cracks have become strongly quartizated, kaolinized, sericitized and in most cases changed to secondary quartzite. Breaking structures have not caused Lower Bajocian rocks to become too complex. The main complexities were generated by subvolcanic masses of rhyolite, rhyodacite and quartz–porphyry composition of Upper Bajocian age which occurred along the Gedabek-Bittibulag depth fault and which began to cool down in the area close to the surface.

Rhyolites and rhyodacites changed to various types of secondary quartzite, and the surrounding rocks changed into secondary quartzite, skarn rocks and hornstones depending upon petrographic, mineralogical and lithological compositions. However, the processes mentioned above did not occur all through the subvolcanic masses and contact rocks. These processes occurred in such areas where there was a constant contact (open channel or open contact zone) between the subvolcano and magmatic source. One of such areas was the Misdag area in which the Gedabek mineral deposit (mine) is located (Baba-zadeh et al, 2012, 2015, 2019).

The Reza gold deposit is located in the Gedabek Ore District of the Lesser Caucasus in NW of Azerbaijan, 358 kms East from the capital city Baku, 48 kms East from the city of Ganja and Ganja airport, 4.7 kms NW from the Gedabek gold copper open mine. The deposit is a well within the Ugur exploration area, NW Area polygon of the Gedabek Contract Area (Fig. 2). Deposit was discovered in 2016 by GEG and was called Reza for honor of Reza Vaziri who is the president of the Azerbaijan International Mining Company, Anglo Asian Mining PLC (AIMC Gedabek Exploration Group, 2014).

The exploration center of the project is the partially backfilled outcrop, independently located on the Google Earth at the Latitude 40°37'13.10"N and the Longitude 45°46'15.34"E. The known gold mineralization has an estimated north-south strike with the length of 400 m and the total area of approximately 20 hectares or 0.2 km². The deposit is enlarged by highly gold-silver as the result of surface outcrop rock chip samples over an area of 2.5 kms North-South by 2 kms East-West, with the Reza gold deposit located in the central part (Fig. 3).

In a geological structure of section there were participated secondary quartzites being formed under the influence of the Atabek-Slavyanka plagiogranite

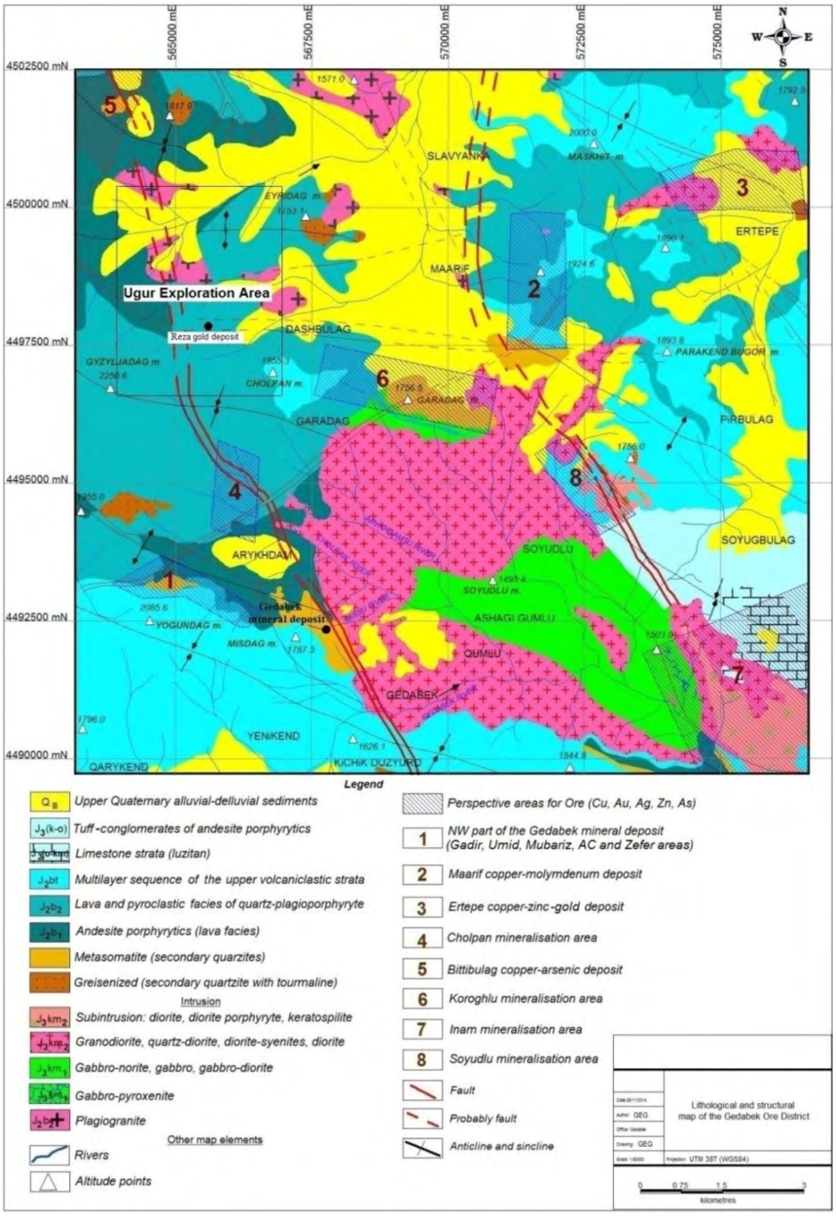

Fig. 1. Lithological-structural map of the Gedabek Ore District (perspective areas for Cu, Au, Ag, Zn & As).

intrusion exposures observed to the north from the gold mineralization area. The area in tectonic attitude is confined to the Gyzyldjadag fault of Northeastern sub-latitudinal strike 80° with a vertical dip. The mineralization zone thickness is within the area bounds up to 80-120m.

Rocks in the alteration zone area crumpled, argillic altered, brecciated, strongly limonitized and hematitized. Hematite is observed there out of metallic minerals. Intensive barite and barite-hematite vein and veinlets, also gossan zones are observed on the surface. The main mineralization zones have been sampled in three trenches at a distance of up to 270m by trenches #1, #2 and #3 and received positive results for gold and silver. Also, there have taken approximately 550 samples from outcrop #1 and #2.

On the main orebody at surface center have occurred secondary quartzites with vein-veinlets barite-hematite mineralization over which remain accumulations of hydrous ferric oxides cementing breccias of quartz and quartzites. The “reddish mass” being oxidation product of stock and stockwerk hematite ores are also observed in erosion parts. Representing typical gossans, these accumulations by the data of trenches for thickness about 5-10 m contain gold 0.3-2.0 g/t and silver 1.0-15.0 g/t.

Local geological-structural setting. The gold mineralization in the Reza deposit developed mainly during the Upper Bajocian tectonic-magmatic cycle.

Tectonic zone is the main host structure for the West (central zone) and East zones of gold mineralization. During Upper Bajocian times, the central tectonic zone was a right-lateral strike-slip fault represented by a number of sub-parallel-

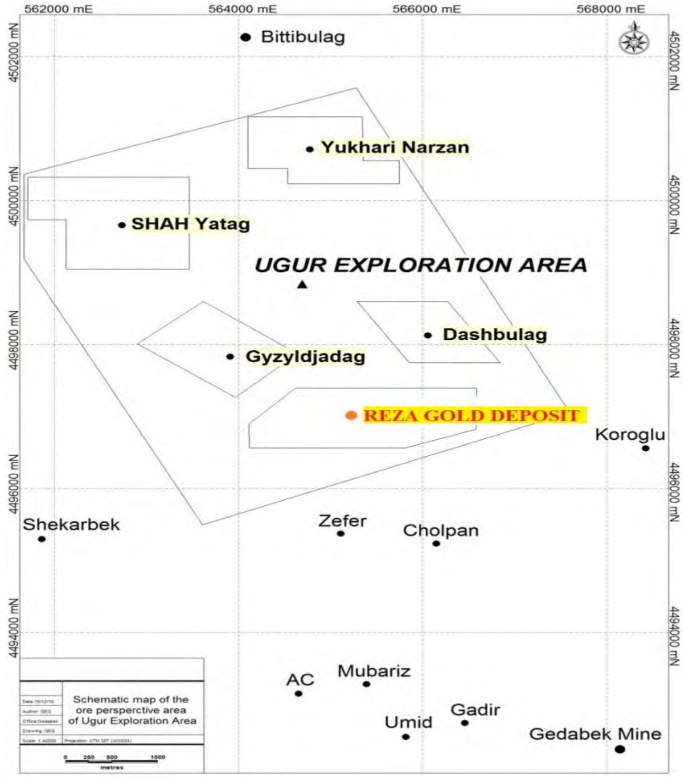

Fig. 2. Schematic map of the ore perspective area of Ugur Exploration Area.

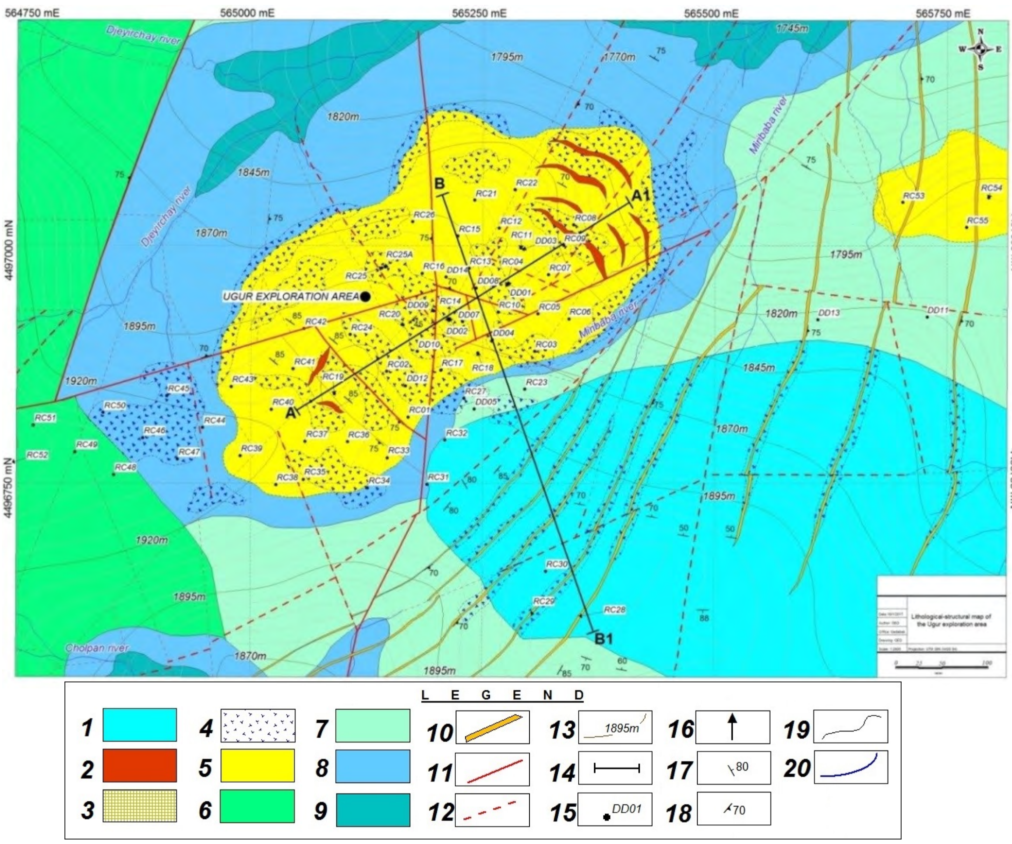

Fig. 3. Lithological-structural map of the Reza gold deposit, Ugur exploration area, scale 1:2800, A3 format, Original scale 1:1 000 (by GEG, 2016).

Legend of lithological-structural map: 1) Andesite tuff agglomerates facie; 2) Gossan; 3) Pyrite stock and stockwerk; 6) Breccia zone of silicified andesite porphyritic rocks; 5) Secondary quartzite; 6) Pyroclastic (from small clastic to lapilli) facie of rhyolite-dacite porphyry; 7) Lava facie of rhyolite-dacite porphyry; 8) Silicified andesite porphyritic rocks; 9) Andesite porphyritic rocks; 10) Quartz porphyry zone (weak hematitized, limonitezation); 11) Faults; 12) Probable faults; 13) Topographic contour line; 14) Cross section lines; 15) Bore holes points; 16) Bore holes ; 17) Deep angle of faults and dykes; 18) Structural elements of rocks; 19) Lithological contact; 20) Rivers.

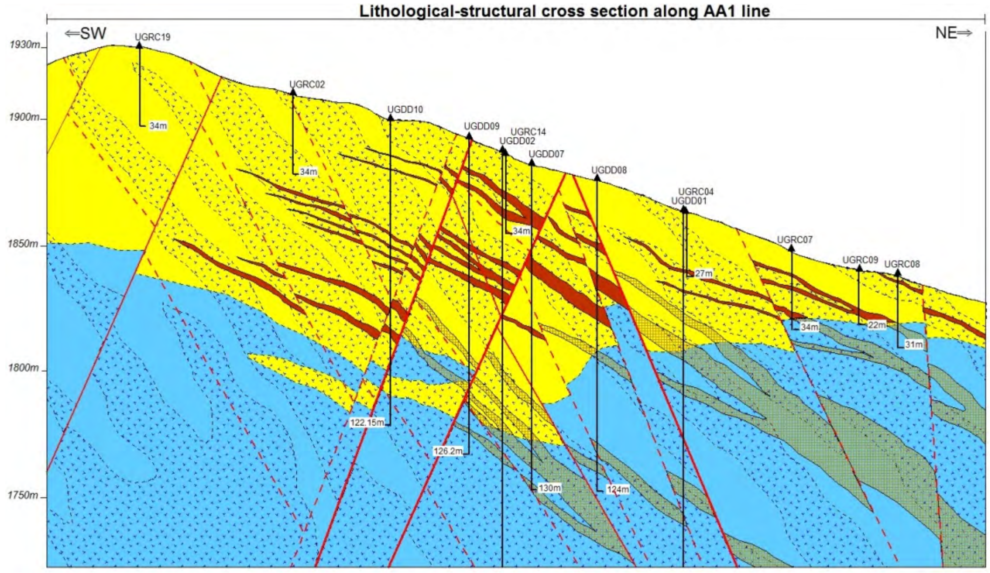

Fig. 3-1. Lithological-structural cross section along AA1 line, Reza gold deposit of the Ugur exploration area.

trending faults (55º-85º) with a combined length of 1-1.5 kilometers. The fault dips from 70º to 80° to the north-west. The faults of the central zone control the hydrothermal metasomatic alteration, gold mineralization, Upper Bajocian Atabek-Slavyanka plagiogranite massive intrusion, and in some cases are the borders of the elevated tectonic blocks formed by Lower Bajocian volcanic rocks.

The East tectonic zone is complicated by the occurrence of numerous related faults such as antithetic and synthetic faults, down throw and thrust faults and intense folding due to faulting. The combination of these structures determines the general morphology of both the oxide and primary sulfide mineralization. Where zones of either fracture cleavage or quartz veinlets occur in drill core, these intervals are described as fault zones. In many cases the intervals of faulting are represented by tectonic breccias in which relics of the host volcanic-sedimentary rocks are cemented by dacitic rock. The tectonic breccias probably formed after emplacement of the sulfide mineralization, during the formation of the sub-longitudinal faults. The intervals of tectonic breccia exhibit lower gold grades in comparison with zones of fracture cleavage and quartz veinlets (Novruzov et al, 2019).

The Reza gold deposit was emplaced in the intersection of NW, NE, N and E trending structural systems regionally controlled by a first order NW transcurrent structure.

Structure geometry and kinematics determined from surface mapping and drilling information suggest that the volcanic sequence hosted at central part might have been accumulated in a "pull-apart" basin controlled by NW structures. These structures were affected by two compressive deformation processes: the first as a result of the N to the NNE sub-horizontal contraction and the second being formed during a post mineral NW contraction.

Field geological exploration information, cross-cutting relationships between structures, veins and brecciation types and hydrothermal alterations styles suggest that the mineralization was controlled by NW brittle dextral shears, associated with E-W left lateral and N-S pure extensional structures, with all them related to the contraction event within a transpressional regimen.

Mineralization and hydrothermal alteration. Main mineralization in the Reza gold deposit consists of hematite-barite-quartz-kaoline veins-veinlets and breccia, pyrite stock-stockverk and quartz-sulfide veins (Fig.4). On the main orebody surface center have occurred secondary quartzites with vein-veinlets barite-hematite mineralization over which remain accumulations of hydrous ferric oxides cementing breccias of quartz and secondary quartzites. The "reddish mass" being oxidation product of stock and stockwerk limonite-hematite ores are also observed in erosion parts. Representing typical gossans, these accumulations by the data of trenches for thickness about 5-10 m contain gold 0.3-3.5 ppm and silver 1.0-45.0 ppm (Hemon 2013, Hemon et al, 2012, 2013, Valiyev et al., 2016, 2018).

There are three zones of gold mineralization within the Reza gold deposit:

- Oxide mineralization;
- Transition zone mineralization;
- Sulfide mineralization.

The oxide gold mineralization consists of clay-gravel weathering crust of kaolinite type. The most

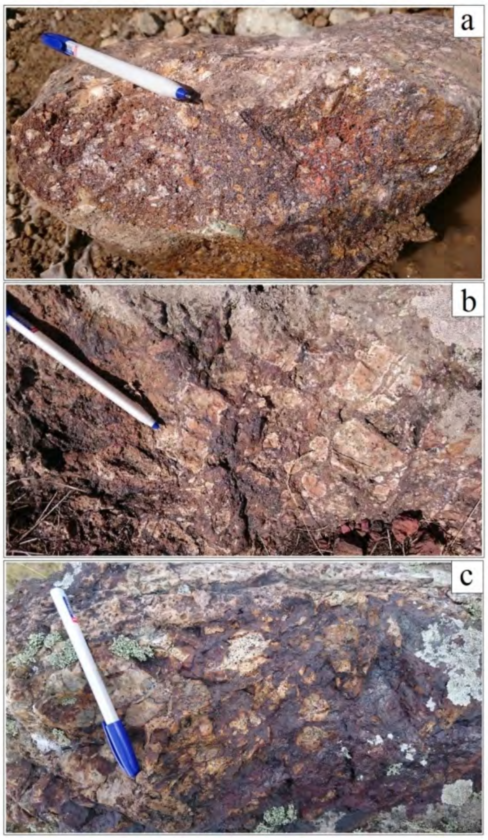

Fig. 4. Breccia, oxide mineralization style of Reza gold deposit: a) Barite-hematite mineralization main orebody (rock sample taken from Djayirchay river by GEG, 2016), Au assay result is 4.96 ppm; b) Secondary quartzite breccies is rectangle form (outcrop, near trench 02), Au assay result is 0.7ppm; c) Secondary quartzite breccies is round form (outcrop, near trench 01), Au assay result is 0.6 ppm.

common color of the oxide is greenish-yellow with different shades of white, brown and red. Strongly oxidized rhyodacite and dacite are represented by light green and grey color rock, oxidized andesite porphyritic rock has a brown and red color.

The gold-bearing mineralization has been oxidized to a depth of approximately 50-100 meters. Locally, in areas of shallow, vertical fracturing and faulting, oxidation has progressed to greater depth than the average profile.

Typically, the gold mineralization is coarser and a minor increase in gold grade occurs within the oxides compared to the original rocks. The nugget effect increase in the gold grade of the oxides does not exceed approximately 10%.

Underlying the oxidized unit, a semi-oxidized horizon displays a partial level of oxidation with some remaining sulfides (transition zone) and may be treatable for its gold content but with lower recoveries.

Mineral associations. The high-grade gold is observed in the following mineral association (based on assay data):

1. Barite-hematite-quartz-kaoline;
2. Hematite-quartz-kaoline;
3. Barite-sulfide-quartz;

The low-grade gold is observed in the following mineral association:

4. Disseminated pyrite;
5. Stock-stockwork pyrite;
6. Disseminated and veinlets covellite-pyrite (+/- turquoise) mineral associations.
7. The 2-3 stages associations are clearly connected with the mineralization process. Each association can occur separately, spots and impregnations. As well, these alteration packages can occur in rocks. Disseminated pyrite observed all of primary rock in the deposit.
8. Barite-hematite-quartz-kaoline. The dominant style of mineralization on the project is from 1 cm to 1 m-wide veins filled with variable amounts of red hematite, specular hematite, and quartz. In outcrop the dominant mineral is earthy red hematite, which is ubiquitous in these stockwork, but remnant patches and stockwork of barite can be found, indicating that the red hematite is likely a weathering product of hypogene barite. Larger stockwork include higher amounts of quartz. Many veinlets contain vugs and open-

space-filling textures of euhedral quartz and kaoline. The majority of hematite-barite-quartz-kaoline mineralization is observed to date occurs as sub-decimeter fractures, either as individual veinlets, zones of parallel sheeted veinlets, or networks of cross-cutting veinlets in some places forming stockwork zones (Fig.5).

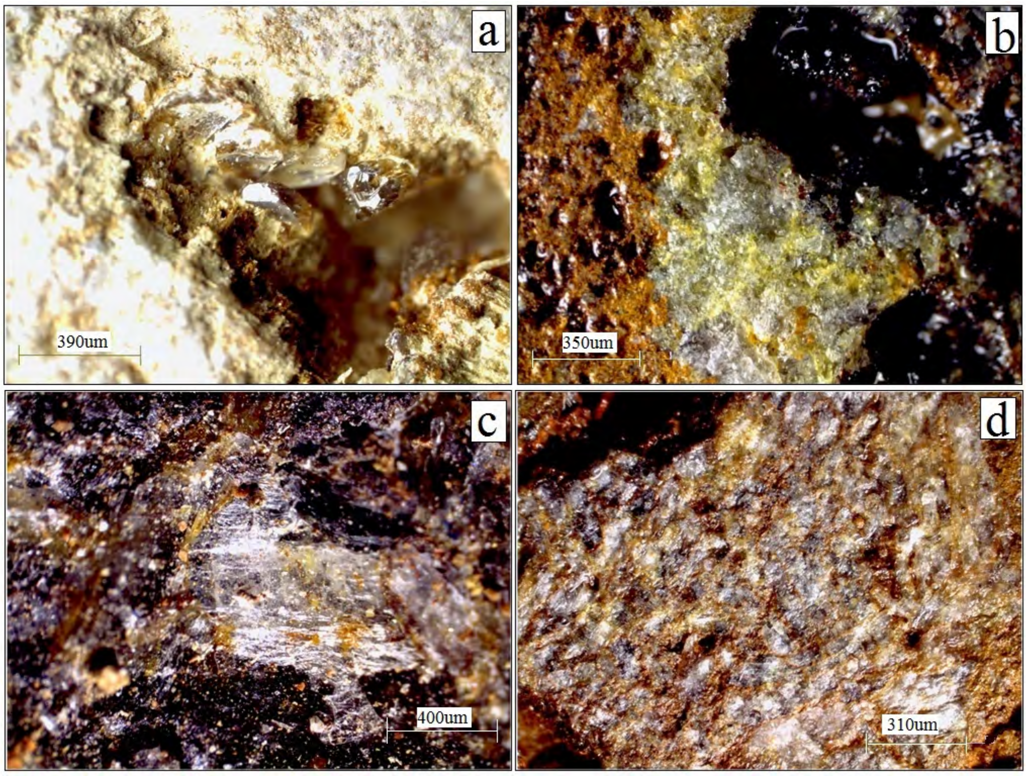

Fig. 5. Barite, barite-hematite, barite-hematite-limonite mineralization main type of orebody from core piece (photos taken under Leica S8AP0 Binoculars): a) barite grains in vugs, secondary quartzite (12.2m, UGDD01); b) barite-hematite-limonite veinlets in secondary quartzite (14 m, UGDD01); c) barite-hematite-limonite mineralization association, breccia form in secondary quartzite (39.4 m, UGDD02); d) barite-hematite-limonite mineralization association, like "fish scale" form in secondary quartzite (40.5m, UGDD02).

The hematite-quartz-kaoline association is the earliest stage and can occur in both mineralized zones and in silicified host rocks. Macroscopically this association exhibits brown red coloration of accompanying quartz. The thickness of the stockwork veinlets ranges from 1 millimeter to 3-5 centimeters. The borders of this style of alteration are usually uneven, often exhibiting pinch and-swell forms and relics of the original rocks.

Barite-sulfide-quartz is the main mineral association that is of economic interest. This association forms thin (a few millimeters to 1-2 centimeters) veins and small impregnations within sericitized and silicified rocks. The spatial occurrence of the hematite-pyrite-quartz and barite-sulfide-quartz association forming single veins is common. In this case, the earlier hematite-pyrite-quartz association occurs in the center of rock fragments while the barite-sulfide-quartz association occurs as a selvage. Sometimes hematite-pyrite-quartz and barite-sulfide-quartz cross-cut each other and/or occur separately.

Disseminated pyrite. The first stage of mineralization is mainly represented by disseminated pyrite occurring together with quartz and adularia alteration through the below contact of the deposit. Gangue minerals are mainly represented quartz and adularia, and minor chalcopyrite. The size of disseminated pyrite is inferior to 1 mm, but the intensity of pyrite dissemination is variable in different parts of the andesite porphyry (Fig.6).

Stock and stockwerk pyrite mineralization observed in the sulfide zone of the deposit.

The Pyrite-covellite-quartz association is less common than the barite-quartz-sulfide association and usually forms veinlets, spots and disseminated aggregates in host (below contact rocks-rhyolite and rhyodacite) rocks disseminated pyrite occurs. Pyrite and covellite are the main minerals of the association. Pyrite occurs as grains (3-5 millimeters) in quartz and rarely as vein-like aggregates and selvages on quartz spots up to 0.5-1 centimeters in thickness. Covellite usually occurs as needle-like crystals, from 2 to 8 millimeters long, and occurs around pyrite and sometimes replaces pyrite on its

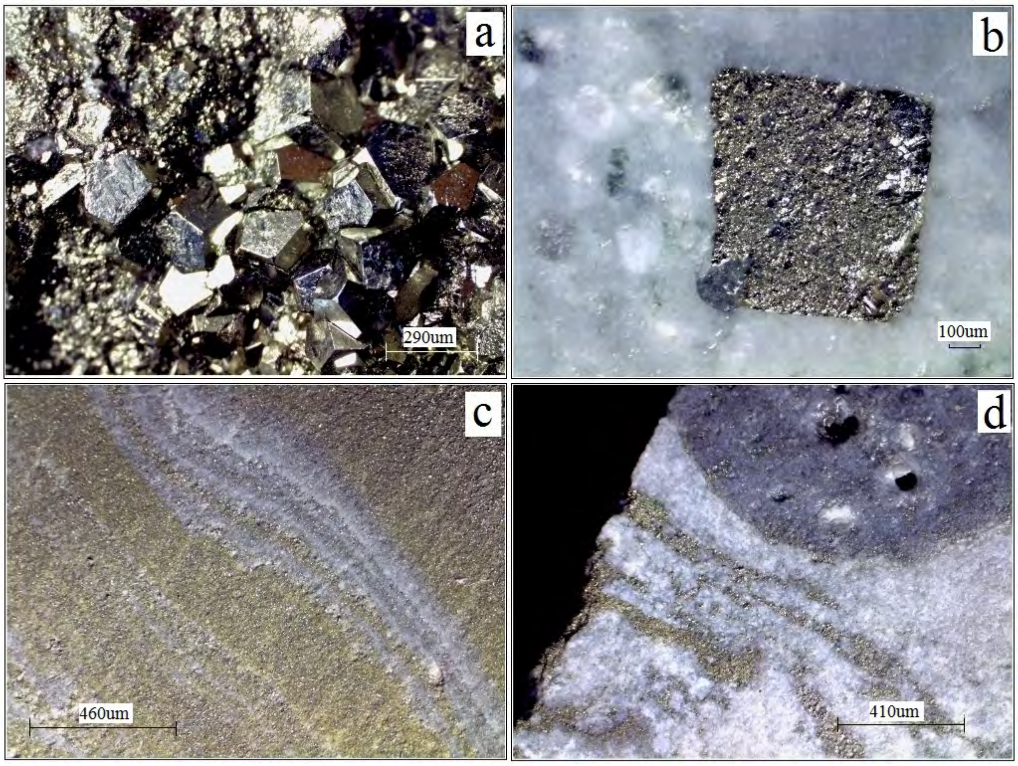

Fig.6. Pyrite mineralization type of sulfide orebody, Reza gold deposit: a) Dodecahedron pyrite crystal (70.7 m, UGDD03); b) (319.2 m, UGDD02); c) Banded pyrite-quartz vein (116.2 m, UGDD02); d) Pyrite veinlets in secondary quartzite (89.2m, UGDD02).

boundaries (up to complete replacement forming covellite pseudomorphs). Wolframite (?) also occurs irregularly in veinlets and disseminated of pyrite-covellite mineral association (Fig. 7).

Ore minerals. The ore minerals are concentrated essentially as breccia-stockwork and disseminated type mineralization in central part of the deposit. The stockwerk zone has been developed due to ore-associated silica precipitation following the second boiling of the hydrothermal system, which was triggered by the Atabek-Slavyanka plagiogranite intrusions.

Ore minerals are mainly disseminated as fine grains in the stockwerk of the brecciated secondary quartzite.

Based on this research, metallic and gangue constituents of the mineralized zones include:

Metallic minerals. Pyrite, Chalcopyrite, Covellite, Chalcantite, Wolframite, Argentite?, Acanthine?, Enargite?, Tenantite?, Arsenopyrite (rare), Cubanite?, Sphalerite (rare), Marcasite?, Tetrahedrite? (?-means that these minerals defined base on XRF data)

Gangue minerals. Barite, Calcite, Quartz, K-Feldspar, Muscovite-Sericite, Plagioclase, Clay (mainly, Kaolinite). Epidote, Chlorite, Hematite, Tourmaline, Turquoise (Fig.8).

Pyrites are observed as broken euhedral to anhedral crystals. The intergrowth of pyrite crystals and host rock inclusions in pyrites are common ore textures. Pyrite is represented by large (0.1 millimeter to 0.3 millimeter and rare 1.0-millimeter diameter) separate crystals or crystalline aggregates. Pyrite has a poor crystal shape. Spatially, pyrite occurs on the vein selvages and in the central part of sulphide mineral spots. Sphalerite forms relatively large (1 to 2 millimeter) grains in quartz veins. Usually, sphalerite grows around pyrite, "curing" small cracks inside pyrite grains. Pyrite and sphalerite occur as separate grains in the impregnated type of mineralization. Disseminated chalcopyrite grains occur in the center of sphalerite grains.

Hematite crystals, which are weathering products of early stage anhedral pyrite, are replaced by siderite due to carbonate-rich weathering processes. Hematite is the most common ore mineral after pyrite, and it has been observed in different mineralogical features. The hematite contains randomly oriented crystals of barite and quartz in different sizes and shape. Textural relations suggest that the quartz is a replacement product of chalcopyrite.

Quartz is the main mineral of this association. The grain size ranges from 0.01 to 0.1 millimeters with the 0.01-0.03 millimeter grain size being the most prevalent. Coarse-grained quartz (usually 0.07 to 0.09 millimeter in diameter) occupies the central parts of small veins and spots. Quartz grains exhibit round shapes and/or oblong forms. Hematite is

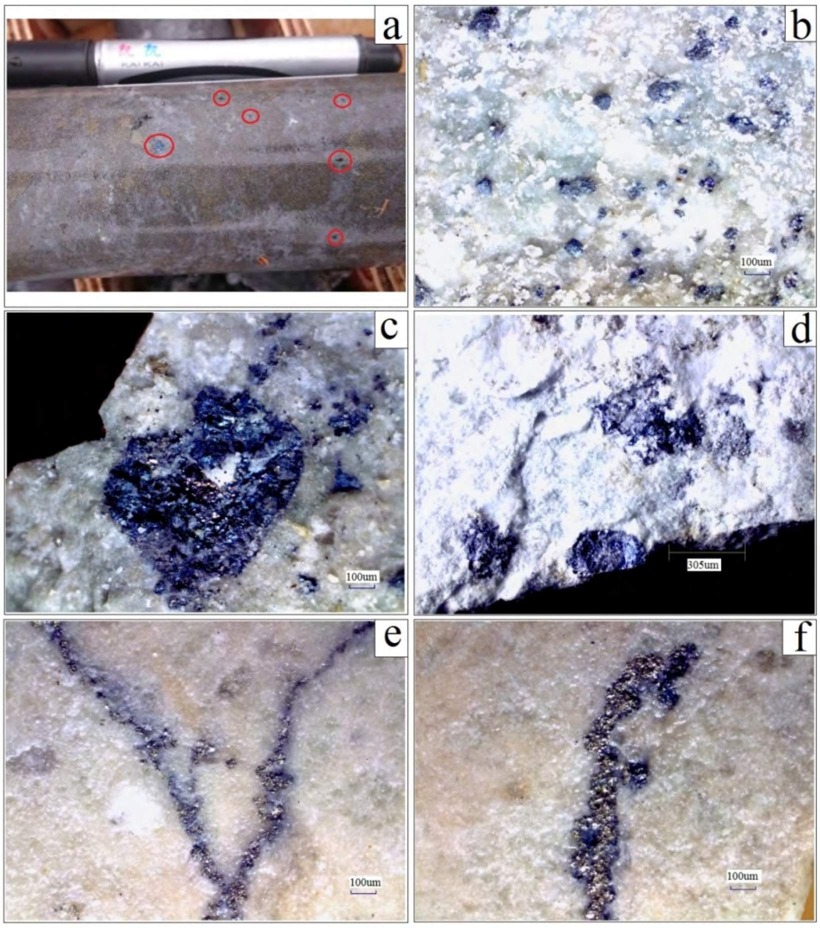

Fig. 7. Sulfide mineralization style of Reza gold deposit: a) covellite minerals grains into secondary quartzite (from core piece); b) covellite grains (little size); c) covellite-pyrite -/+ wolframite (high grade by XRF-?) minerals grains (coarse size); d) covellite -/+ wolframite (high grade by XRF-?); e) & f) covellite-pyrite veinlets in rhyodacite (?).

unevenly distributed and usually colors fine-grained quartz in some instance. Pyrite exhibits pyritohedron shapes and rarely cubic crystal habits. The pyrite grains range in size from 0.05 to 0.2 millimeter and occur inside clear quartz grains.

In addition to the minerals described above, thin-

Fig. 8. Turquoise ($CuAl_6(PO4)_4(OH)_8{\cdot}4H2O$) mineralization in the Reza gold deposit: turquoise minerals observed on fractures, rhyodacite core piece (the upper); turquoise mineral fragment in rhyodacite rock, photos taken under Leica S8AP0 Binoculars (the following).

flakes of sericite can occur in the center of the quartz veins and spots and can be replaced by chlorite or chlorite-ankerite. Chlorite occurs only in contact with carbonate with sericite forming the edges between these minerals. Chalcopyrite rarely occurs together with pyrite and forms thin veinlets and impregnations.

Hydrothermal alteration. At the deposit, mineralization occurs with strong argillic alteration, with stockwork, disseminated, and veinlets, within secondary quartzite breccias and mineralized east-northeast structures. Oxide facies dominate at the surface but become sulfide mineralization at depths of less than 50-100 m.

Two distinct alteration events are recognized by GEG AIMC, 2016. During emplacement, the early granodiorite intrusions altered the andesite porphyritic rocks. Later, the main mineralization altered the silicified andesite porphyritic and secondary quartzite rocks generating a zoned alteration assemblage that includes moderate to selective quartz, sericite, argillic and silicification alteration among others. Alteration to kaolinite and iron oxides occur locally, as does an apparent epithermal overprint that produces banded and chalcedonic textures and which may be associated with observed barite-hematite and pyrite mineralization.

Gold at Reza deposit is concentrated in the gossan, argillic and limonitized-hematitized alteration zones and low grade gold in phyllic zone (pyrite stock and stockwerk). Transition zone at the oxide-phyllic zones boundary is largely north-south trending fault-controlled silica flooding, which becomes northeast striking, east and west of the boundary. The deposit alteration studies about 20-25pcs samples from intrusive and host rock showed in order of dominance, intermediate argillic, propylitic, advanced argillic, phyllic, silicification and gossan alteration zones.

The dominant types of alteration on the project are hematite alteration and secondary mineralization of pyrite (Fig. 9). Minor silicification and clay alteration of andesite porphyritic rocks are also present. Hematite alteration consists of hematite staining surrounding hematite-barite-quartz association. This type alteration is accompanied in some places by silicification and limonitezation.

Deposit type. The remote sensing anomalous (in NW and SW) area is believed to remain open in all directions under shallow, post-mineral cover. Deposit alteration signature has characteristics which suggest the current outcrop level may be near the top of a mineralized, gold-bearing high sulfidation epithermal (HSE) system (Hedenquist, 1988, Sillitoe, 2003, 2010; Simmons, 2005).

The gold mineralization at the deposit is interpreted as forming in shallow high sulfidation epithermal systems. The mineralization has been noted to occur in two different styles:

- well-confined hydrothermal breccias;
- associated with pyrite stock-stockwork.

The majority of the deposit material and current estimates are formed within the barite-hematite-quartz-kaoline mineralization in the secondary quartzite rocks.

The main brecciation and stockwork are hosted within secondary quartzite, sometime massive silicified andesite porphyritic rocks.

Outcropping gold mineralization at the project is oxidized with no sulfides recognized at surface. Mineralization is hosted by brecciated, and intense advanced argillically-altered andesitic volcanic and possible domes, including large areas of «powdery» probably alunite-opal alteration (Fig. 10). The outcropping alteration at the deposit is typical of the upper steam-heated levels of high-sulfidation epithermal (HSE) deposits, which in most mineralized systems of this type, may cap higher-grade gold mineralization which is hosted by underlying vuggy and oxide zones.

From our current mapping and sampling, the gold mineralization at the deposit appears to form

Fig. 9. Hematite mineralization, oxide zone: Left side-hematite vein on andesite porphyritic fractures and Right side- barite veinlets oxidation secondary quartzite.

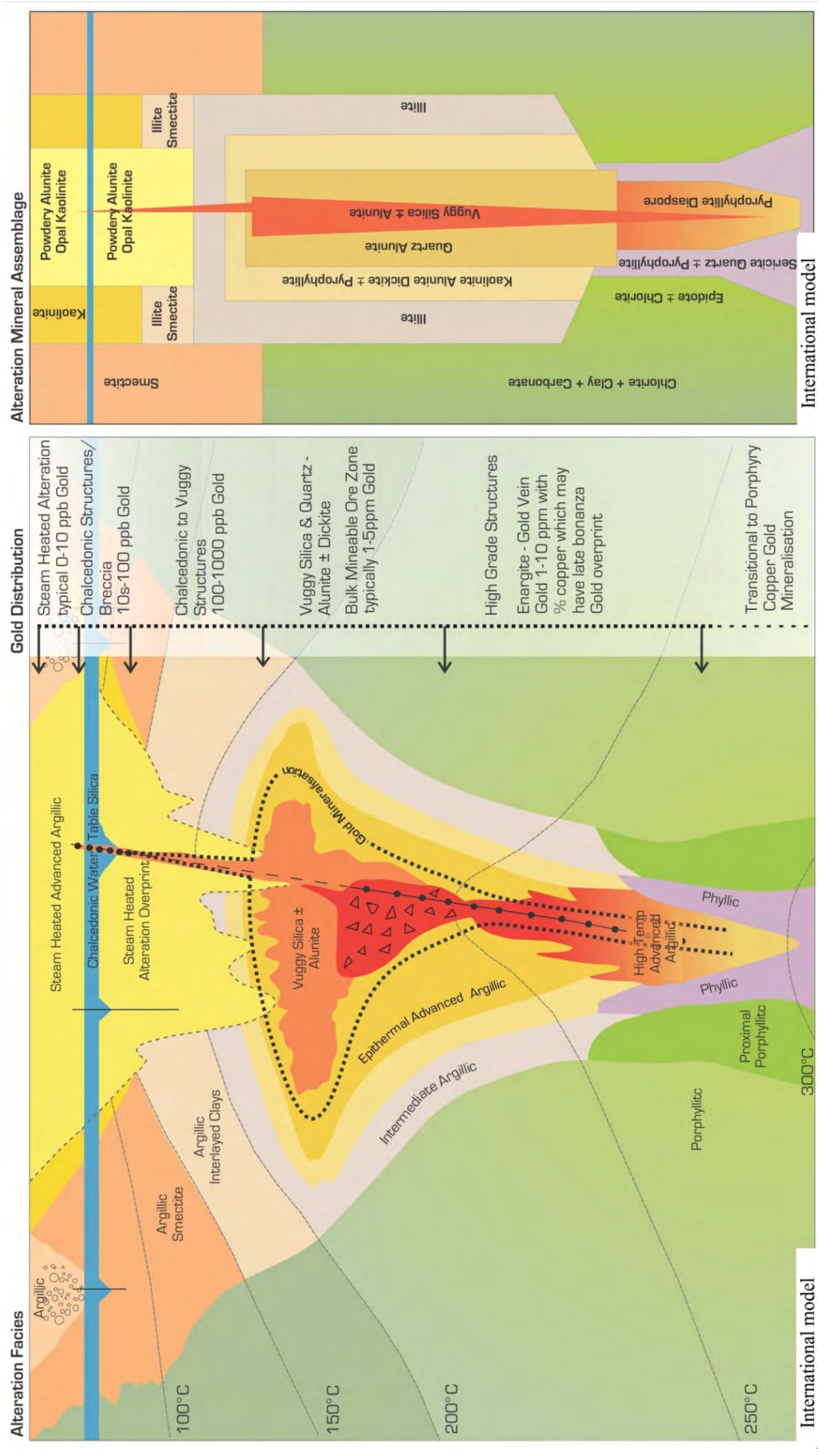

Fig. 10. International high sulfidation epithermal model for the Reza gold deposit.

a crescent shape surrounding a «core» of barite-hematite mineralization in advanced argillically and silicification - altered porphyritic andesite host rock.

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Sacral Heritage of the Carpathian Region and Management of its Resource Component in Tourism Activity

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Abstract. The Carpathian Recreation/Tourism Region (hereafter – CRTR) in Ukraine is a unique territory featuring the sacral historic-cultural heritage of different-time periods beginning from Ancient Rus, Lithuanian, Ottoman, Austro-Hungarian and until Polish, Romanian, Czech and Ukrainian times. This is why it seems urgently necessary to assess in as much detail as possible the sacral historic-cultural heritage (hereafter – HCH) of the Carpathian Recreation/Tourism Region in Ukraine and provide for the mechanisms of management of the same so that the aforementioned heritage will be as quickly and intensely as possible involved into a common cultural and tourism space and trans-border cooperation with neighboring EU countries, that is, Romania, Slovakia, Poland, Hungary and Moldova. For this purpose different types of conservation status (e.g., UNESCO and national heritage) were considered and spatial differences in the sacral historic-cultural monuments (hereafter – HCM) were analyzed through the assessment of their number, modified indices of the sacral objects' concentration, coefficients of localization and educational value, etc, with application of the methods of partial and integral point-based ranking and cluster analysis with respect to the 58 administrative districts of the region. Following the survey of the CRTR where the sacral HCM were found to be the range from average to very good condition , and proceeding from ethnographic-historical context, the region was spatially differentiated into the Roztotsko-Boykivskyy Meso-District on the northwest, the Hutsul Meso-District in the Prykarpattia, and the Bukovynian Ukrainian-speaking and Romanian-speaking micro-districts in the Prypruttia. Among the 6 formed district-status CRTR clusters, 3 of them (27.6% of the administrative districts of the region) were assessed as the most optimal for the purpose of efficient tourism/excursion activity (hereafter - TEA) and its management, while average geometric indices of all aforesaid coefficients ranged from the above-average (4.10) to the highest (7.59) throughout the whole region. It is suggested to achieve efficient tourism management within the studied territories by way of more active introduction of a series of previously tested pilgrimages and educative-religious tours, as well as through different interstate events of trans-border cooperation. All these would increase the competitiveness of the HCM-oriented tourism industry, be helpful in ascertaining which specifically attractive territories should receive investment, and help integrate the Carpathian Region of Ukraine into the common cultural and tourism space of the EU countries.

Key words: sacral heritage, tourism, rating, cluster, destination, Carpathians

Сакральна спадщина Карпатського регіону та управління її ресурсною складовою в туристичній діяльності

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Анотація. Карпатський рекреаційно-туристичний регіон (надалі – КРТР) в Україні – це унікальна територія, де представлена сакральна історико-культурна спадщина різних часових періодів: від давньоруського, литовського, османського, австро-угорського до польського, румунського, чехословацького та українського. Тому вкрай нагальною є всебічна комплексна оцінка забезпечення та механізми управління сакральною історико-культурною спадщиною (надалі – ІКС) Карпатського туристично-рекреаційного регіону в Україні для інтенсивнішого їхнього залучення до єдиного культурного, туристичного простору та транскордонного співробітництва разом із сусідніми країнами ЄС: Румунією, Словаччиною, Польщею, Угорщиною та Молдовою. Для цього бралися до уваги різні охоронні статуси (спадщина ЮНЕСКО, національний) та просторові відмінності сакральних історико-культурних пам'яток (надалі – ІКП) через оцінку їхньої кількості, модифіковані показники концентрації сакральних об'єктів, коефіцієнти локалізації та пізнавальної цінності, застосовуючи в оцінюванні методи часткової та інтегральної рейтингової бальної оцінки та кластерного аналізу за 58 адміністративними районами регіону. За підсумками наукових вишукувань КРТР забезпеченості сакральними ІКП від пересічної до дуже доброї, виходячи з етнографічно-історичного змісту, у просторовому вимірі регіон диференційований на Розтоцько-Бойківський мезорайон на північному заході, Гуцульський мезорайон на Прикарпатті та Буковинський україномовний і румуномовний мікрорайони в Припрутті. З-поміж 6 сформованих кластерів районного статусу в КРТР 3 (27,6% адміністративних районів регіону) оцінюються як найоптимальніші стосовно обставини для найрезультативнішої туристично-екскурсійної діяльності (надалі ТЕД) та її менеджменту, а їхні пересічно геометричні показники усіх раніше зазначених коефіцієнтів коливаються від вищих за середні (4,10) до найвищих (7,59) значень по всьому досліджуваному регіону. Для ефективного туристичного менеджменту визначених територій пропонується активніше впровадження низки апробованих в регіоні паломницьких та пізнавально-релігійних турів та різних міждержавних заходів транскордонного співробітництва, що дасть змогу підвищити конкурентоспроможність туристичної галузі з використанням сакральних ІКП регіону, визначити його конкретні території інвестування, туристичної привабливості та інтегрувати Карпатський регіон України до єдиного культурного та туристичного поля разом із країнами ЄС.

Ключові слова: сакральна спадщина, туризм, рейтинг, кластер, дестинація, Карпати

Introduction.

The present-day stage of the development of society clearly presents the problem of the rebirth and preservation of its culture and spirituality, and the sacral objects as key elements of cultural richness and development of religious tourism represent the essential part of the regional HCM. The oblasts that cover the Carpathian Region bordering the EU countries (Romania, Slovakia, Poland) and comprise the common Carpathian Recreation Zone of Ukraine are distinctive for the enormous concentration of sacral tourism objects, which can be explained by the Carpathian Region's long-time experience as part of the Austro-Hungarian Empire, Poland, Romania and Czechoslovakia (Fig. 1).

Assessment of sacral tourism potential (hereafter – STP) of regional heritage lies in substantiation of its efficient management and the use of its objects in spatial and systemic-structural establishment of the place of specific resource within this or that territory for the purpose of definition of the ways of its subsequent development. Domestic science is represented by almost no studies related to management of tourism of religious objects and provides no parameterized assessment of sacral monuments with application of mathematical methods. The necessity of solution of these questions preconditioned the rationality of our choice as well as predefining its tasks and directions.

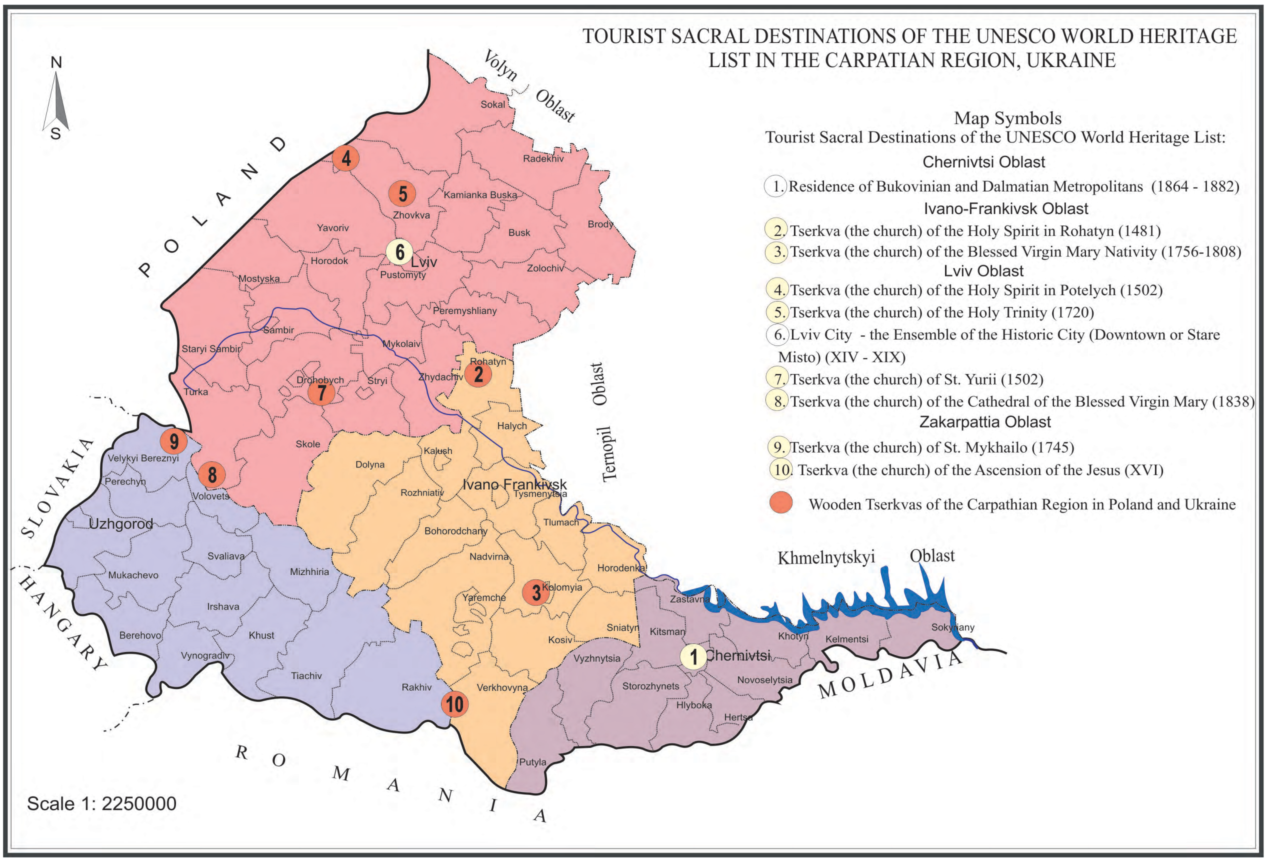

Fig. 1. The Map of Geographical Layout of the Study Area and its Main Sacral HCH of the UNESCO World Heritage List

The aim of the study.

The aim of the article is to study and analyze the sacral historic-cultural heritage potential of the Carpathian region and its administrative districts in Ukraine, and to substantiate the expediency of the development and management of tourism activity here based on its sacral clusters.

Review of previous research.

The spatial structure of STPs in Chernivtsi Oblast's in the Peredkarpattia (Pre-Carpathians) and the Carpathians was the area of scientific interest of I. Kostashchuk and A. Hutsuliak (2014). I. Kostashchuk is also known for his research into theoretical-methodological problems of the religious confessional space of Ukraine and its influence upon social processes (Kostashchuk, 2018, 2019 a). Religious tourism as a subject matter of research is found in the works by I. Dobynda (2014). In particular, she is known for elaboration of sacral tourism routes in the Volyn (Dobynda, 2016). The resource component of Buddhist international and local tourism in China was described in the works by the American and Chinese scientists, Robert Shepherd and Gu Huimin respectively. The authors came to the conclusion that the pilgrimages in China are rather a religious than a tourism phenomenon and that the rush of tourists to the destination Wutai Shan, China , endangers the uniqueness of the local cultural landscape (Shepherd R. & Huimin Gu., 2012).

Problematic questions and promising regions for international religious tourism in Ukraine on the basis of HCM of different religions and ethnic groups that may become the objects of interest of international tourists were considered by Yu. Danilyeva (2012). Similar problems within the territory of the Southern Urals were discussed by a group of authors from Bashkotorstan (Khairetdinova et al., 2016), while Belarusian researchers added the question of development of ethnographic tourism (Blishch, 2014). D. Pryimak (2015) focused on the philosophical view on the factors of religious tourism pilgrimage considering it to be a social phenomenon. The resource base possessed by Ukraine for the purpose of development of pilgrimage and excursion forms of tourism was analyzed by I. Lytvyn (2014), while its regional aspect was considered on the example of Prykarpattia by V. Shykerynets (2012). The pilgrimage resource base from Nepal to Australia was characterized by du Cros H. and Johnston C. (2002), while religious journeys as a form of tourism and pilgrimage were characterised by Olsen D. and Timothy D. (2006).

The essence and the principles of the logistic approach to efficient organization of tourism space on the example of religious tourism, and the analysis of the structure and the components of the same were discussed in the study by I. Smyrnov. The author's assessment of the logistics in this segment of tourism services resulted in the development of measures to help preserve sacral resources (objects) from excessive use by tourism (Smirnov, 2015). The importance of solution of the problem of preservation of hieratic sacral resources possessed by indigenous people of Southern Siberia through tourism and use of these resources in different tourism routes was actualized in the scientific community by E. Chaykina. The results of her work were suggested to be used for stimulation of tourism business in the Altai (Chaikina, 2017).

S. Panchenko's research is perhaps the only study devoted to management of religious monuments tourism in Ukraine. The author emphasized the huge potential of religious tourism in this country, which is yet not appropriately made use of. This is why the arrangement of favourable conditions for high-quality religious tourism involving domestic and foreign tourists requires a more active state policy and involvement of investments into the tourism industry of Ukraine (Panchenko, 2019). Problems of management of sacral resources in the tourism industry and the strategy of their development in the Podillia (Ukraine) were highlighted by Hordyskyi Y. and Manko A. (2012). Present-day resources of cultural heritage, its different statuses, assessment and importance, as well as the system of its management were the basis of the contribution by Taylor K. (2004). Positive experience of management of stable tourism in religious and holy places of local communities in California and Thailand was disclosed in publication by the American scholars Levi D. and Kocher S. (2009).

A thorough search into management of religious tourism is found in the work presented in the collective monograph entitled *Religious Tourism and Pilgrimage Management*. In particular, the authors focus on concepts of religious tourism and its management, motivations behind the phenomenon of pilgrims' migrations, examples of international religious tourism case studies in South-East Asia, Israel, Ireland, Northern Portugal, Argentina, Lebanon, and Malta (Rai & Griffin, 2015).

Present-day problems of managing 166 objects of world religious heritage were analyzed by Myra Shackley on the example of cultural tourism. She considered different religious traditions of predominantly Christian culture (51%) in the Northern hemisphere, as well as the questions of balanced preservation of sacral objects for the purpose of improvement of tourism service (Shackley, 2001).

To summarize, the studies of sacral and religious monuments in the Ukrainian regions generally emphasize the description of the resource component, while questions of HCM management for balanced improvement of tourism service are considered superficially, with no regional specifications or insights into adjoining countries and their parts. It is therefore for the first time in Ukraine that such studies of spatial content with application of mathematical multifactor methods are conducted for the CRTR as an essential part of the large Carpathian Tourism/Recreation Zone that also covers territories in Poland, Slovakia and Romania. The major task of this article lies in assessment of tourism sacral potential in Ukrainian administrative oblasts covered by the CRTR for the purpose of strengthening the efficiency of its financial management in conditions of decentralization of economics that started in 2014, and subsequent formation of tourism attractiveness of the country's new financial centers, i.e., territorial communities. A cartographic model of total ranking positions of each administrative oblast with respect to four assessed components shall be one of the results of this work. Finally, it will allow us to outline the major territorial units possessing the greatest, average and the least potentials of a sacral HCH's integral value. We cannot but accentuate that the study results and the methods of counting the ranking positions of the administrative-territorial units with respect to total value of their HCH sacral objects can be made use of by other local bodies of self-government and respective institutions for the purpose of efficient management of their tourism-excursion activity (hereafter – TEA). Besides, they can also be helpful in similar studies of the Carpathian Tourism/Recreation Zone pertaining to Poland, Slovakia and Romania.

Methodology.

The research on HCH is based on several criteria where the majority of researchers consider either their material component or recreation (recreation/tourism) resources. The point-based assessment of sacral HCH as tourism destinations was suggested by O. Beidyk (2001) and T. Bozhuk (2008). I. Kostashchuk, having combined methodological developments of the aforesaid authors, retains point-based assessment, together with O. Lyubitseva (2009), in his own way. The researcher suggests such assessment criteria as the object's geographical disposition (type of settlement and the number of its inhabitants, transport accessibility, etc.), its compositional value, presence of sacred places, architectural appearance and value, the infrastructure of the object itself , historical significance, church (confessional) significance, attractiveness and accessibility for visiting, availability of information resources, and the object's present-day state. On the whole, each criterion can be awarded a maximum of 5 points , though this value may increase to 10 if the above-suggested coefficients are applicable (Kostashchuk, 2017, 2019 b). However, even with such detailed methodological analysis, there remains a role for subjective assessment through verbal explanation in the absence of clear quantitative/qualitative parameterization and with no possibility of application of specific mathematical methods of research.

The study of the region's sacral heritage (the Carpathian region, Ukraine) was carried out using the method of K. Polyvach, which was declared by her in her dissertation research and monographs, in which she offers comprehensive geographic methods for an integral assessment of the cultural heritage of a region or regions (Polyvach, 2007). To ensure the correctness of the comparison of regions, in addition to general statistical indicators of the number of sacral tourist objects represented in the State Register of Monuments of Ukraine, the authors also used regional coefficients: the modified coefficient of concentration of tourist destinations and the localization coefficient of objects, calculated using geographical methods of research. Therefore, in order to determine the status capacity of differently weighted religious sites-destinations, account was taken not only of their number, but also their conservation status as an integral object of tourist and excursion activity, proceeding from the coefficients proposed in formula 1 (Krool et al., 2018):

$$C_{HCP}(s) = \sum k \times x1 + k \times x2 + k \times x3 + k \times x4 \quad (1),$$

where: $C_{HCP}(s)$ is the status capacity of historical and cultural significant sites (including sacral) of different weights (values); k is the coefficient of the "status weight" of the historical and cultural significant sites, where 1.2 is obtained by the significant sites of international (UNESCO heritage) value, 1.0 by the sites of national importance, 0.9 by the sites of state importance, 0.75 by the sites of local significance; and x1, x2, x3, x4 the number of historically and culturally significant sites, respectively, of international, national, state and local status. The component part of the C_{HCP} (s) and the same formula for the sacral HCM is the coefficient of conservation status ($C_{c.s.}$).

Two other criteria (modified indicator (coefficient) of concentration of sacral monuments concentration and the localization of sacral HCM) were counted according to K. Polyvach's formula (Polyvach, 2012).

The second factor component of the partial rating of the regional historical and cultural heritage in the study is a modified indicator (coefficient) of concentration of tourist destinations (MIs.m.c.). It takes into account both the number of sacral historical and cultural destinations, the total area on which they are located, and the tourists who visited them for a certain period of time, usually a year. The methodology of its calculation is presented in K. Polyvach using the formula (Polyvach, 2007):

$$W = V / \ln B \qquad (2),$$

where: W – modified index (coefficient) of concentration of tourist destinations; V – absolute indicator of the number of objects of the sacred heritage in the region; S – area of the studied regions; P – population of the region; B – √SP.

The third factor component of the partial rating assessment of the regional heritage is the localization of the sacral HCM. This factor takes into account the specific weight of the territory by the number of sacral destinations and the specific weight of the territory by area. The order of its calculation is presented in the formula "3" (Polyvach, 2012):

$$K_{loc} = Ch / Cs \qquad (3),$$

where: Ch – specific weight of the region by the number of objects of historical and cultural heritage; Cs – the region's share by area.

The component part of the K_{loc} and the same formula for sacral HCM is the index of localization of sacral objects ($L_{s.o.}$).

And, finally, the fourth criterion, i.e., the coefficient of educational value of sacral tourism destinations ($C_{e.v.}$) was counted as the proportion between the total points gained in the result of assessment of the sacral HCR of a specific settlement or locality and the maximum possible points provided in the assessment scale by (Kravtsiv et al., 1999):

$$C_{e.v.} = A / A_{max} \qquad (4),$$

where: A is a sum of points of educational value of historic-cultural tourism resources in a specific settlement, territory (block); A_{max} – maximum possible points according to point-based assessment scale (Kravtsiv et al., 1999).

Consequently, the total rank value of all four factor components and their partial assessments of the region's sacred and religious heritage gives, as a result, an overall score in points (according to the rating) that a region has received. It is important that this evaluation has an inverse relationship (lower scores correspond to better and enhanced potentials) for effective and promising use in domestic and international tourism and excursion activities, as well as within the framework of EU associate membership and wider cross-border cooperation between Ukraine, Romania, Poland, Slovakia and other countries of the entire Carpathian recreational and tourist zone.

Research results and discussion.

Historic-cultural resources (hereafter – HCR) is the totality of monuments of material and spiritual culture created in the process of historic development of a specific territory that now have become objects of tourists' interest. The HCR include educational, event-related, ethnographic and biographic-social resources (Malska & Antoniuk, 2008). Hence, the HCH represents the totality of objects of cultural heritage inherited by mankind from previous generations. Sacral resources of religious pilgrimage and educative/informative content with respect to the material and spiritual culture heritage within a specific territory comprise an essential part of the aforesaid resources.

The CRTR of Ukraine covers four administrative oblasts consisting of 58 administrative districts, and features 774 sacral national-status HCM and those included in the UNESCO World Heritage List. The monuments' assessment showed that 29 administrative districts unevenly located in all oblasts of the region, namely, Lviv, Ivano-Frankivsk, Zakarpattia and Chernivtsi administrative oblasts, manifest the values of the coefficient of conservation status ($C_{c.s.}$) which are higher than the mean values of the same within the region (8.7) (see Table 1). The greatest share (62%) out of their totality is concentrated in Lviv Oblast – 479 HCM, 16% - in Ivano-Frankivsk (125 HCM), 15% in Zakarpattia (114 HCM), and 7% in Chernivtsi oblasts (56 HCM). With respect to number of HCM that exceeds the average values for the Carpathians, 2/3 of them are found on the territory of Lviv Oblast (418 HCM), 18% - Zakarpattia Oblast (112 HCM), 13% - Ivano-Frankivsk Oblast (83 HCM), and 3% - Chernivtsi Oblast (22 HCM).

According to the total score of the sacred heritage objects by the administrative units of the entire Carpathian region and the methodology for calculating the modified concentration indicators, the localization coefficient of tourist and religious excursion destinations and coefficient of their cognitive value, we calculated the total ratings of the administrative-territorial units for each of the four indicators (see Table 1).

The values exceeding those of the modified index of sacral monuments concentration ($MI_{s.m.c.}$) in the Carpathian Region (10.48) were observed in its 29 territorial units, where 17 or 58.6% account for administrative districts of Lviv Oblast, 5 and 5 (17.2% and 17.2% each) – Ivano-Frankivsk and Zakarpattia oblasts, and 2 (6.9%) – of Chernivtsi Oblast. Absolute leadership in respect of monuments' concentration is taken by the City of Lviv,

Table 1. The total rating of sacral HCM of national status and UNESCO World Heritage List in the administrative districts of the Carpathian region, Ukraine

Administrative districts	Coefficient of conservation status ($C_{c.s.}$)	Rating, points	Modified index of sacral monuments concentration ($MI_{s.m.c.}$)	Rating, points	Localization index of sacral HCM ($L_{s.o.}$)	Rating, points	Educative value of sacral tourism destinations ($C_{e.v.}$)	Rating, points	Total rating, points
Berehovo	6.0	41.0	7.97	40	0.620	34	0.545	56.0	171.0
Bohorodchany	7.0	36.5	8.03	39	0.575	37	0.583	54.0	166.5
Brody	18.0	14.0	19.69	16	1.019	19	0.667	50.0	99.0
Busk	21.0	12.5	26.30	11	1.610	11	0.913	35.0	69.5
Chernivtsi city	7.2	33.5	8.97	35	3.089	4	0.600	52.5	125.0
Drohobych	17.2	15.0	17.56	19	0.925	23	0.956	30.0	87.0
Halych	6.0	41.0	8.07	38	0.545	40	0.857	39.0	158.0
Hertsa	12.0	21.0	23.51	12	2.493	7	1.000	17.0	57.0
Hlyboka	5.0	44.5	5.89	45	0.488	42	1.000	17.0	148.5
Horodenka	3.0	51.5	3.78	50	0.264	50	0.600	52.5	204.0
Horodok	23.0	10.5	27.08	10	2.077	9	1.000	17.0	46.5
Irshava	8.0	31.0	8.09	37	0.556	39	0.889	36.0	143.0
Ivano-Frankivsk city	4.0	47.5	6.17	43	3.136	3	0.800	45.0	138.5
Kamianka Buska	11.0	23.5	12.96	25	0.833	27	1.000	17.0	92.5
Khotyn	1.0	57.0	1.22	58	0.092	58	1.000	17.0	190.0
Khust	11.0	23.5	11.17	28	0.741	31	0.917	34.0	116.5
Kitsman	10.0	27.5	12.34	26	1.081	18	1.000	17.0	88.5
Kolomyia	7.2	33.5	7.19	42	0.473	43	1.200	1.0	119.5
Kosiv	40.0	4.0	41.36	4	2.663	6	0.870	38.0	52.0
Lviv city	85.6	1.0	153.1	1	308.7	1	0.251	58.0	61.0
Mizhhiria	27.0	8.5	30.96	6	1.520	13	1.000	17.0	44.5
Mostyska	8.0	31.0	9.53	31	0.621	33	1.000	17.0	112.0
Mukachevo	6.0	41.0	6.00	44	0.395	45	0.667	50.0	180.0
Mykolaiv	6.0	41.0	7.37	41	0.584	36	1.000	17.0	135.0
Nadvirna	12.0	21.0	11.04	29	0.609	35	0.923	33.0	118.0
Novoselytsia	2.0	53.5	2.28	54	0.178	53	1.000	17.0	177.5
Perechyn	2.0	53.5	3.07	52	0.208	52	1.000	17.0	174.5
Peremyshliany	13.0	19.0	16.76	20	0.930	22	0.813	44.0	105.0
Pustomyty	43.0	3.0	42.46	3	2.962	5	0.843	41.0	52.0
Putyla	7.0	57.0	10.25	30	0.520	41	1.000	17.0	145.0
Radekhiv	12.0	21.0	13.86	23	0.689	32	1.000	17.0	93.0
Rakhiv	10.2	25.5	9.09	34	0.354	46	1.020	2.0	107.5
Rohatyn	15.2	17.0	20.18	14	1.224	16	0.691	47.0	94.0
Sambir	14.0	18.0	15.56	21	0.984	20	0.933	32.0	91.0
Skole	35.0	5.0	38.00	5	1.563	12	1.000	17.0	39.0
Sniatyn	4.0	47.5	5.05	47	0.438	44	1.000	17.0	155.5
Sokal	21.0	12.5	19.47	17	0.878	24	0.750	46.0	99.5
Sokyriany	1.0	57.0	1.38	56	0.099	56	1.000	17.0	186.0
Staryi Sambir	27.0	8.5	27.26	9	1.424	15	0.844	40.0	72.5
Storozhynets	2.0	53.5	1.93	55	0.113	55	1.000	17.0	180.5
Stryi	7.0	36.5	8.26	36	0.569	38	1.000	17.0	127.5
Svaliava	1.0	57.0	1.28	57	0.098	57	1.000	17.0	188.0
Tiachiv	6.0	41.0	4.79	48	0.217	51	1.000	17.0	157.0
Turka	27.2	7.0	30.75	7	1.500	14	1.007	4.0	32.0
Tysmenytsia	3.0	50.5	3.37	51	0.269	49	1.000	17.0	167.5
Uzhgorod	4.0	47.5	4.46	49	0.302	48	0.667	50.0	194.5
Uzhgorod city	4.0	47.5	12.07	27	6.564	2	0.500	57.0	133.5
Velykyi Bereznyi	10.2	25.5	15.36	22	0.828	28	1.020	2.5	78.0
Verhovyna	16.0	16.0	20.25	13	0.834	26	0.941	31.0	86.0
Volovets	10.0	27.5	17.84	18	1.207	17	1.000	17.0	79.5
Vynogradiv	9.0	29.0	9.34	33	0.848	25	0.563	55.0	142.0
Vyznytsia	2.0	53.5	2.35	53	0.145	54	1.000	17.0	177.5
Yaremche	8.0	31.0	13.55	24	0.801	29	1.000	17.0	101.0
Yavoriv	23.0	10.5	20.07	15	0.975	21	1.000	17.0	63.5
Zastavna	7.0	36.5	9.46	32	0.742	30	0.875	37.0	135.5
Zhovkva	47.4	2.0	44.07	2	2.403	8	0.668	48.0	60.0
Zhydachiv	5.0	44.5	5.50	46	0.330	47	0.833	42.0	179.5
Zolochiv	28.0	6.0	29.77	8	1.671	10	0.824	43.0	67.0
Average value in region	**8.7**	**-**	**10.48**	**-**	**0.775**	**-**	**0.856**	**-**	**108.0**

Source: authors of paper

where the said concentration of sacral tourism and excursion objects exceeds by 3.5 times the values manifested by the runner- up Zhovkva District (44.07). It should be noted that the first ten places with respect to values of the modified index are in its absolute majority represented by administrative districts of Lviv Oblast, with the minor exceptions of Kosiv District (41.36, Ivano-Frankivsk Oblast) and Mizhhirya District (30.96, Zakarpattia Oblast). Though not so markedly, administrative districts of Lviv Oblast have taken the lead in the second ten, with a few more inclusions of two administrative districts of Ivano-Frankivsk Oblast (Verkhovyna and Rohatyn), one district of Zakarpattia Oblast (Volovets), and one – of Chernivtsi Oblast (Hertsa). It is only in the third ten that Lviv Oblast's leadership comes to naught despite the fact that the third ranking ten is headed by Sambir District of Lviv Oblast (15.56) and represented by two more districts of the same oblast (Radekhiv and Kamianka-Buzka). The third ten is distinctive for the fact of being represented by administrative units of all other oblasts of the Carpathian Region, that is, Zakarpattia Oblast (Velykyi Bereznyi District, Khust District and Uzhgorod City), Ivano-Frankivsk Oblast (Nadvirna District and Yaremche City Council), and Chernivtsi Oblast (Kitsman District and Putyla District).

For a more detailed explanation of the presence and location of sacral sites in the Carpathian region, it is worthwhile analyzing the distribution of the localization coefficients for sacral heritage sites. In this case, the optimal value should approach 1, since here the ratio of the shares of sacral objects of the specific weight of the areas on which they are represented is taken into account.

In this context, the four leading places are taken by the oblast centers where localization of sacral HCM ($L_{s.o.}$) predefines the most favourable territorial component which is complemented by transport accessibility. Hence, the hierarchy between the oblast capital cities has formed as follows: Lviv (308.7), Uzhgorod (6.564), Ivano-Frankivsk (3.136), and Chernivtsi (3.089). On the whole, the optimal structure (over 1.000) is possessed by 15 more administrative-territorial units, 9 of which (Pustomyty, Zhovkva, Horodok, Zolochiv, Busk, Skole, Turka, Staryi Sambir, Brody) refer to Lviv Oblast (52.6%), and two districts each represent the remaining oblasts (Kosiv and Rohatyn, Hertsa and Kitsman, Mizhhiria and Volovets administrative districts of Ivano-Frankivsk, Chernivtsi and Zakarpattia administrative oblasts respectively). It should also be noted that 10 more administrative-territorial units within the region of this study that manifest not so favourable concentrations of sacral HCM (coefficient of localization is less than 1), nonetheless show the above-average values if compared to all remaining administrative districts. The majority of these districts once again are located on the territory of Lviv Oblast (Brody, Sambir, Yavoriv, Peremyshliany, Drohobych, Sokal) with 2 districts each located in Ivano-Frankivsk (Verkhovyna and the lands of the Yaremche City Council) and Zakarpattia (Vynogradiv and Velykyi Bereznyi) oblasts with no representation of Chernivtsi Oblast.

The districts in the Carpathians referred to as unique with their specific sacral HCM and thematic TEA specialization are only those where the coefficient of educative value ($C_{e.v.}$) for such territories is ≥1. There are now 29 such districts almost evenly distributed in all oblasts save for Ivano-Frankivsk Oblast. 9 districts each, or 31.0% represent Lviv and Chernivtsi oblasts, and 24.1% - Zakarpattia Oblast. A weighty though not dominant share of sacral HCM in the region predefines the attractiveness of these resources in the territories where $C_{e.v.} < 1$ but still exceeds the average value (0.856) in the Carpathian Region (8 territorial units). Such situation is characteristic for 37.5% of the districts of Ivano-Frankivsk Oblast (Nadvirna, Kosiv and Halych districts), while it is the least characteristic in Chernivtsi Oblast (only Zastavna District).

Thus, the dominance or trailing position of the districts in the four parameters assessed above predefined their respective ranking position with respect to each of the parameters, as well as allowing the establishment of their total values and ranking positions to be expressed in points. In these cases, a sufficient reserve in the districts or their larger territorial formations follows from the least ranking points, thus outlining them into a space possessing the best sacral-resource component and preconditions of their efficient management within the frame of the TEA.

Now the totality of ranking points in the Carpathian Region ranges from 33 (Turka District, Lviv Oblast) to 204 (Horodenka District, Ivano-Frankivsk Oblast), and the average value for all 58 administrative-territorial units is 107 points. These figures gave grounds to combine the total ranking points of administrative districts and other territories into 7 groups, three of which are referred to as having an adequate (81-100 points), good (61-80 points) and very good (up to 60 points), and three more as insufficient (121-140 points), poor (141-160 points) and the poorest (161 and more points) reserve of sacral HCM as compared to the group with average reserve (101-120 points) of the same in the Carpathian Region.

As follows from the assessed parameters and their total ranking points, very good and good HCM reserves and preconditions for the TEA-related efficient management are found in 14 administrative districts and in the City of Lviv. Their core area (66.7%) is located on the territory of Lviv Oblast from Roztochchia to Peredkarpattia in Boykivshchyna, while the districts have on a

50/50 basis a good and very good HCM reserve. A very good sacral HCM reserve is also found in the Zakarpattia's Boykivshchyna (Mizhhirya District – 44.5 points), Halychski Hutsulshchyna (Kosiv Distriuct, Ivano-Frankivsk Oblast - 52 points), and in Chernivtsi Oblast (Hertsa District - 57 points). A good HCM reserve is observed in 71.4% of districts of Lviv Oblast , which supplement the territorial massif of its Roztotsko-Boykivska part together with Velykyi Bereznyi (78 points) and Volovets districts (79.5 points) from Boykivshchyna in the Zakapattia.

9 more administrative districts of the region show a sufficient sacral HCM reserve and practically the same potentiality for their efficient management within the TEA frame. As in the previous situation, Lviv Oblast dominates with 2/3 of the sufficient reserve being represented by its districts from Roztochchia to Peredkarpattia in Boykivshchyna, together with the adjoining Rohatyn District (94 points). One more unit manifesting sufficient sacral HCM reserve, namely, Verkhovyna District (86 points), adjoins the Hutsul Meso-Region together with the aforementioned Kosiv District. Kitsman District (88.5 points) of Chernivtsi Oblast is outlined as a separate territorial element.

Average reserve of sacral HCM is characteristic for the territory of the Yaremche City Council and 6 administrative districts, almost 29 % of which are located in Lviv Oblast (Mostyska and Peremyshliany districts). Hutsul Meso-District covers the Rakhiv District (Zakarpattia Oblast), the town of Yaremche and the southern portion of Nadvirna District (Ivano-Frankivsk Oblast) (from 101 to 118 points). These are supplemented by Kolomyia District (119.5 points) in Pokuttia. Khust District (Zakarpattia Oblast, 115.5 points) represents the buffer locality between the mountain territory of the Carpathians and the Zakarpattia Lowland, and shows a below average sacral HCM reserve.

The other massifs of insufficient, poor and very poor HCM reserve in the Carpathian Macro-Region are found in the far east of Northern Bessarabia comprising Novoselytsia, Sokyriany and Khotyn districts (176.5-189 points), the Bukovynian portion of Chernivtsi Oblast (Vyzhnytsia and Storozhynets districts, 176.5 and 179.5 points respectively), in Pokuttia (Tysmenytsia and Horodenka districts, 166.5 and 204 points respectively), and in part of Boykivshchyna (Bohorodchany District, 166.5 points) of Ivano-Frankivsk Oblast. Besides, the far south west of the Carpathian Region within the borders of the Zakarpattia features the essential territorial massif of very poor sacral HCM reserve, formed of Berehovo, Perechyn, Mukachevo, Svaliava and Uzhgorod administrative districts , which show 170-193.5 points.

Thus, according to point-based division into very good, good, sufficient and average sacral HCM reserve, the CRTR features the *Roztotsko-Boykivskyy Meso-District* in the northwest, *Hutsul Meso-District* in the Prykarpattia and the *Bukovynian Ukrainian-speaking* and *Romanian-speaking micro-districts* in the Pryprutia. The first-mentioned territory is the largest since it covers 22 administrative districts and Lviv City. The second is represented by 6 administrative units, while the Ukrainian-speaking and Romanian-speaking Bukovynian micro-districts are quantitatively the smallest territory, since they are formed of only 1 district each.

The method of cluster analysis has become an appropriate extension in our search into still more concentrated disclosure of spatial elements of different hierarchical levels for the purpose of the efficient TEA-related sacral HCM management. Having applied the *Statistcis_10*, we analyzed four parameterized massifs of statistical data for each of 58 districts within the Carpathian Region. The most optimal and vivid combinations of regional sacral HCM can be observed in 6 clusters when the complete linkage method, Manhattan Matrix, Step 19 are applied (see Fig. 2). These combinations should become the basis for common managerial solutions for better TEA-related sacral HCM-based development. The situation with the city Lviv is specific, since its manifested parameters and closeness of links are essentially different from those of the rest and cannot therefore be combined with any of the remaining clusters since it requires its own unique strategy of sacral HCM management.

The *first district cluster* includes 12 administrative districts and 2 oblast capital cities, or 24.6% of their totality within the studied region located within the 4 administrative oblasts: Berehovo, Halych, Mykolaiv, Bohorodchany, Stryi, Irshava, Kolomyia, Mostyska, Putyla, Zastavna, Chernivtsi City, Rakhiv, Vynohradiv, and Uzhgorod City (Administrative - Territorial Cluster Composition, see Fig. 2). The cluster is characteristic for the poorest preconditions for TEA-related sacral HCM-based development since it manifests one of the lowest values of the coefficients of conservation status, localization of sacral objects and modified index of sacral objects concentration (5th position with respect to each coefficient) and educative value (6th position) (Table 2). We should also note that the range of difference in the values was, in particular, 4-10.2 for $C_{c.s.}$ (the difference between its maximal and minimal values reached 6.2); 0.354-6.564 for $L_{s.o.}$ (6.21), 0.5-1.2 for $C_{e.v.}$ (0.7), and 7.19-12.07 for $MI_{s.m.c.}$ (4.88).

Quantitatively, the *second district cluster* is the largest since it combines 16 administrative units: Hlyboka, Zhydachiv, Mukachevo, Tiachiv, Horodenka, Tysmenytsia, Sniatyn, Uzhgorod, Khotyn, Svaliava, Sokyriany, Novoselytsia, Vyzhnytsia, Storozhynets, Perechyn districts and the Ivano-Frankivsk City. Administrative-

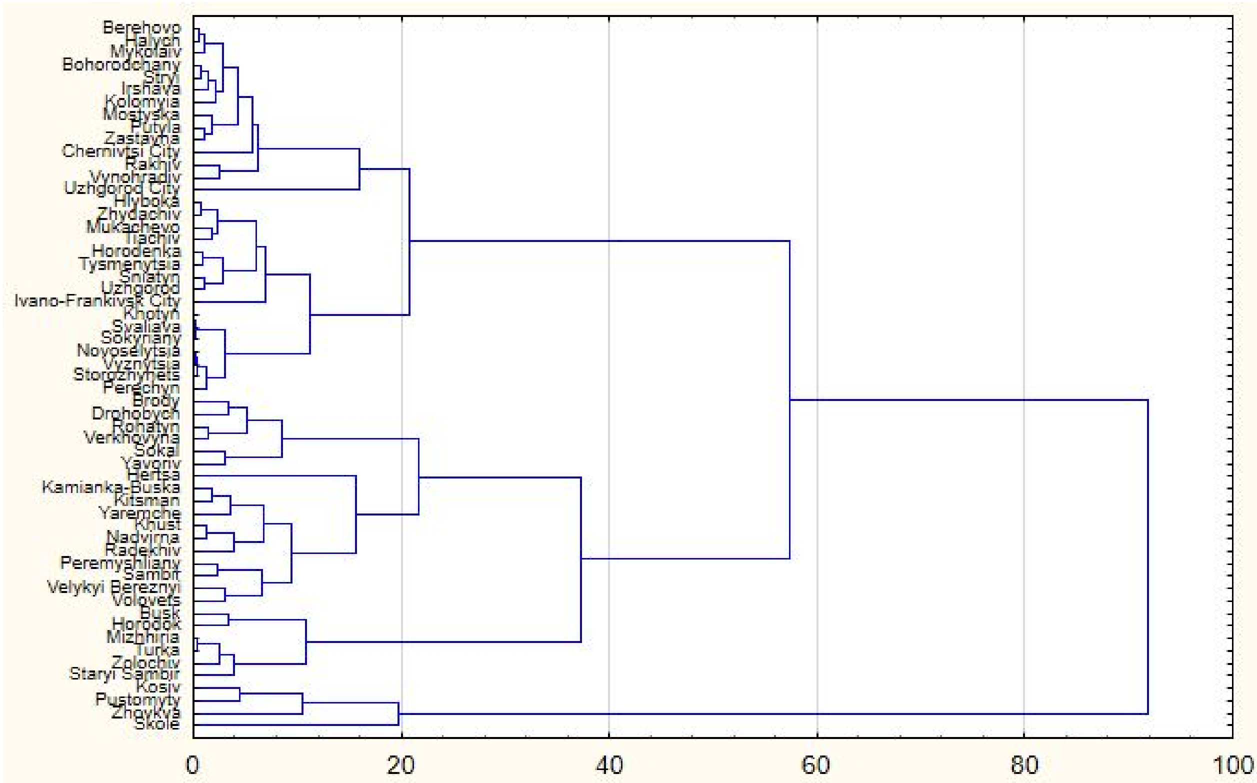

Fig. 2. The Administrative and Territorial Cluster Composition of Sacral HCM of National Status and UNESCO World Heritage List in the Carpathian region, Ukraine (Source: authors of paper)

territorial units within this cluster manifest the poorest average $C_{c.s.}$, $MI_{s.m.c.}$ and $L_{s.o.}$ values (all of them take 6^{th} place), thus confirming the fact of the most unfavourable TEA-related development preconditions. Such conclusion is not even shattered by the value of $C_{e.v.}$, according to which territorial components there won 3^{rd} positions. The coefficients within this cluster ranged as follows: 5 for $C_{c.s.}$, 4.95 for $MI_{s.m.c.}$, 3.04 for $MI_{s.m.c.}$ and 0.4 for $C_{e.v.}$.

Nearly the best preconditions for TEA-related sacral HCM-oriented development have formed in territorial units of the *third district cluster*. In particular, with respect to manifested average geometrical values of $C_{c.s.}$, $MI_{s.m.c.}$ and $L_{s.o.}$ they took 3^{rd} ranking positions. The value of the $C_{e.v.}$ is the only exception (territorial units have won only the last but one (5^{th}) position). Still, it can be safely asserted that rather acceptable TEA-related conditions are observed in 6 administrative districts (10.5% out of the totality), namely, Brody, Drohobych, Rohatyn, Verkhovyna, Sokal and Yavoriv. Besides, the difference between the maximal and minimal coefficient values is greater than that in two previous clusters only for the $C_{c.s.}$ = 7 (16-23), while it is essentially smaller for three remaining coefficients: $MI_{s.m.c.}$ = 2.69 (17.56-20.25), $L_{s.o.}$ = 0.39 (0.834-1.224), and $C_{e.v.}$ = 0.33 (0.67-1).

Satisfactory TEA-related figures are observed in 10 districts and 1 town of oblast subordination combined into the *fourth district cluster*, namely, Hertsa, Kamianka-Buzka, Khust, Kitsman, Nadvirna, Radekhiv, Peremyshliany, Sambir, Bereznyi, Volovets and the town of Yaremche (19.3% out of the totality). This conclusion is confirmed by the 4^{th} ranking positions of average coefficients that characterize the spread of sacral HCM, i.e., $C_{c.s.}$, $MI_{s.m.c.}$ and $L_{s.o.}$. And it is only the value of the $C_{e.v.}$ that puts the administrative-territorial formations of the fourth cluster in the 1^{st} position. However, in our opinion, the aforesaid value cannot significantly affect TEA-related preconditions within this territorial combination, and, after all, this becomes clear from the essential difference between the maximal and minimal sacral HCM-related values.

Thus, the said difference with respect to $C_{c.s.}$ was the least if compared to other territorial clusters making 3 (10-13, 6^{th} position), and the largest with respect to $MI_{s.m.c.}$ making 12.47 (11.04-23.51, 1^{st} position).

Nearly the best preconditions for TEA-related sacral HCM-oriented development have formed in 6 administrative districts which represent within the CRTR the *fifth* combination of *clusters*, namely, Busk, Horodok, Mizhhirya, Staryi Sambir, Turka and Zolochiv. The presence and concentration of sacral HCM there is confirmed by consistently high average geometric values of $C_{c.s.}$, $MI_{s.m.c.}$, $L_{s.o.}$ and $C_{e.v.}$ (each district's 2^{nd} position). At the same time, the range of intervals for the first coefficient was 21-28 (difference - 7), the second – 26.3-30.96 (4.66), the third – 1.5-2.077 (0.577), and the fourth – 0.824-1 (0.176).

Table 2. The Clusters' Average Value of Sacral HCM of National Status and UNESCO World Heritage List in the Carpathian region, Ukraine

Clusters	Coefficient of conservation status (Cc.s.)	Modified index of sacral monuments concentration (MIs.m.c.)	Localization index of sacral HCM (Ls.o.)	Educative value of sacral tourism destinations (Ce.v.)	Average value
1 Cluster	6.96	8.75	0.768	0.800	**2.47**
2 Cluster	2.71	3.19	0.249	0.898	**1.18**
3 Cluster	18.20	19.51	0.968	0.823	**4.10**
4 Cluster	11.08	14.56	0.941	0.962	**3.48**
5 Cluster	25.39	28.63	1.621	0.928	**5.75**
6 Cluster	41.10	41.41	2.333	0.837	**7.59**
Average value	**12.58**	**14.53**	**0.933**	**0.873**	-

Source: authors of paper

And, finally, *the sixth district cluster* is formed of only 4 administrative districts, namely, Kosiv, Pustomyty, Zhovkva and Skole, all of them manifesting the highest average geometrical values in respect to the first three parameters: $C_{c.s.}$ = 41.1; $MI_{s.m.c.}$ = 41.41, and $L_{s.o.}$ = 2.33. Though highly attractive in this cluster (0.84), $C_{e.v.}$ takes a back seat to the fifth, fourth and second clusters. Nonetheless, the aforesaid facts pointedly confirm the formation on the territory of these administrative-territorial units of the best preconditions for the high-performance tourism and excursion activity. We cannot but accentuate that the intervals of the extreme values for $C_{c.s.}$ and $MI_{s.m.c.}$ are very high and exceed the same for all other clusters. Thus, the $C_{c.s.}$ manifests the values of 35-47.4 (1^{st} position), $MI_{s.m.c.}$ – 38-44.07 (2^{nd}), and it is only the $L_{s.o.}$ that shows 1.56-2.96 (4^{th}), and the $C_{e.v.}$ – 0.67-1 (3^{rd} -4^{th}) – see Fig.3.

Following the results of the cluster and point-based analysis for the purpose of management of sacral HCM resource component, all of the aforesaid preconditions form here an essential potential for the development and efficient management of tourism and excursion activity in Carpathian region, which is annually visited by over 1.5 million tourists. As of this day, foreign and domestic tourists are already served with a number of excursion and pilgrimage tours in Chernivtsi and Ivano-Frankivsk Oblasts, developed and offered by us to the local tourist business. The tours, in the first place, coincide with the territories of the third, fifth and sixth clusters as parts of the Hutsul Meso-District in the southeast and the Bukovynian Ukrainian-speaking and Romanian-speaking micro-districts in the Prypruttia, and in the second, have good perspectives to be incorporated in the religious pilgrimage routes to monasteries and churches under the aegis of the UNESCO ("Sucevița", "Voronets", etc) in the Județul Suceava in Romania.

As follows from this study, intensification of managerial solutions for pilgrimage and excursions in the CRTR's first two clusters is possible through cooperation with staff of respective specialized departments of higher education establishments. To make sacral HCMs more popular it is necessary to develop a transborder strategy of their management in close cooperation with local self-governments, religious communities and their eparchies in border regions of the EU and Ukraine. The bodies and the communities should cooperate to help preserve, protect and restore historic sacral places and objects financed by grants and other funds. The state should develop and realize its program for the development of cultural tourism, and intensely promote the whole Carpathian Region (EU and Ukraine) as a brand and cultural focus within Europe.

Such monuments of folk architecture as wooden sacral structures, the most important of which are included into the UNESCO World Heritage List should become the important objects of unified tourism management in the EU and Ukraine. For example, in addition to the Wooden Architecture Route (Szlak architektury drewnianej), a major tourist route in Poland (507 objects inclusive of those from the UNESCO World Heritage List), and the UNESCO Wooden Churches of the Marmaros in Romania, managers of international tour operators would also have in mind such routes and tours as Sacral Monuments of the Roztochchia, Boykivshchyna and Hutsulshchyna in the Ukrainian Carpathians. All these would increase the competitiveness of the HCM-oriented tourism industry, be helpful in ascertainment of specifically attractive territories to be invested into, and help integrate the Carpathian Region of Ukraine into the common cultural and tourism space of the EU countries.

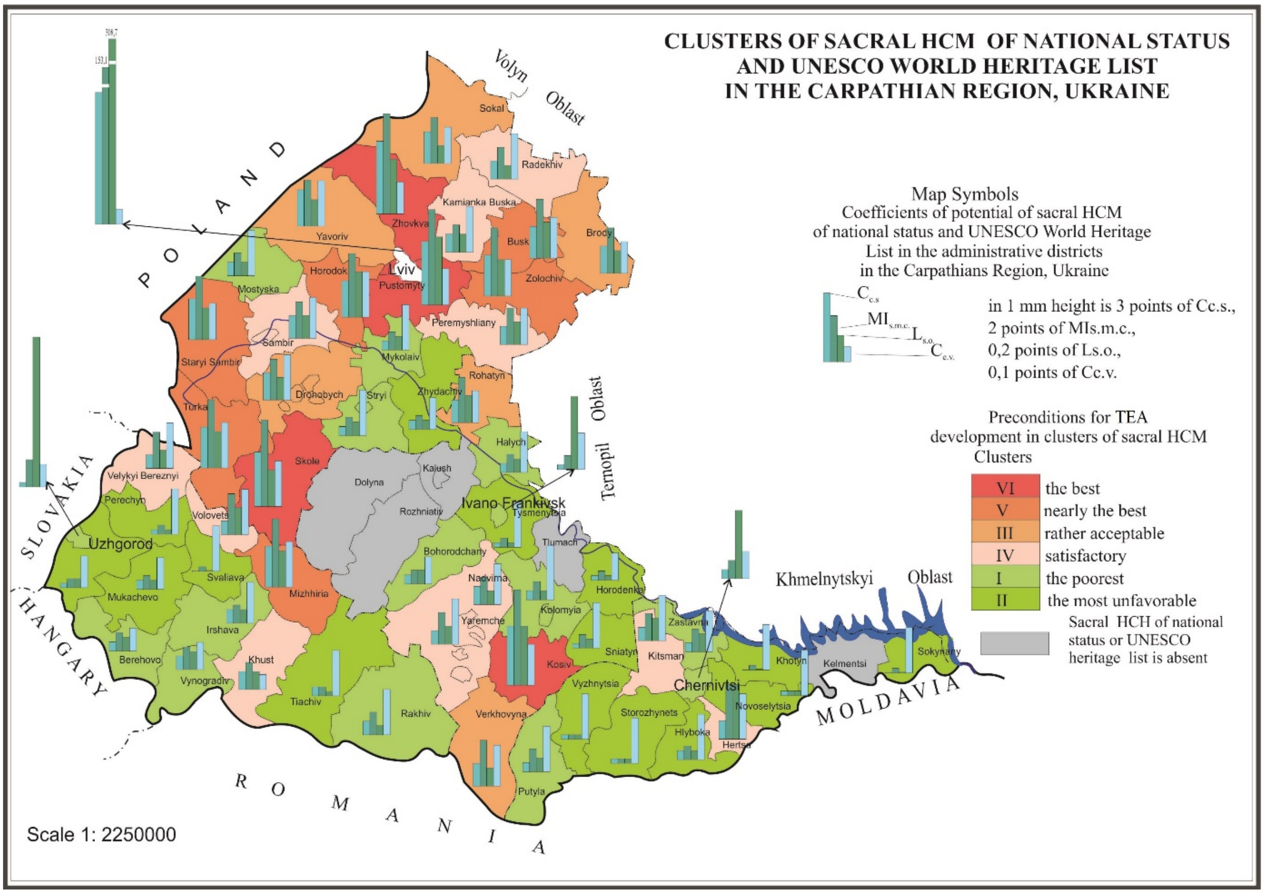

Fig. 3. The Quality of Clusters of Sacral HCM of National Status and UNESCO World Heritage List in the Carpathian Region, Ukraine

Conclusions.

As follows from the results of point-based assessment of the levels of very good, good, sufficient and average reserves of sacral HCM, the CRTR features districts of different hierarchy. The *Roztotsko-Boykivskyy Meso-District* in the northwest, being the largest and showing sufficient, good and very good sacral HCM reserves (less than 100 points), is represented by 22 administrative districts and the City of Lviv. The *Hutsul Meso-District* in the southeast (average, good and very good reserves, less than 120 points, with no districts possessing sufficient reserve) covers 6 administrative units, 5 of which are located in the Peredkarpattia. And the last, the *Bukovynian Ukrainian-speaking* (sufficient reserve, 81-100 points) and the *Romanian-speaking* (very good reserve, less than 60 points) m*icro-districts* in Prypruttia are quantitatively the smallest formations since they are represented by 1 district each.

Almost the most unfavourable preconditions for sacral HCMs -based and fully linked to Manhattan Matrix (Step 19) TEA have been formed in the first (12 administrative districts and 2 oblast centers), and the most massive (16 administrative units) second *district clusters* where 4 assessed coefficients ($C_{c.s.}$, $MI_{s.m.c.}$, $L_{s.o.}$ and $C_{e.v.}$) predominantly showed 5^{th} and the last 6^{th} ranking positions respectively. The fourth cluster with its satisfactory (predominantly 4^{th} position) reserve for TEA-related development in 10 districts and 1 city of oblast subordination is intermediate between the aforesaid two clusters and those that manifest the very good sacral HCM management figures (third, fifth, sixth clusters). Among all values shown by these three, it is the sixth cluster that takes the lead. Though represented by only 4 administrative districts, it shows the highest average geometrical values for the $C_{c.s.} = 41.1$; $MI_{s.m.c.} = 41.41$ and $L_{s.o.} = 2.33$ (1^{st} position). The third and the fifth clusters, with 6 administrative districts each, predominantly rank 3^{rd} and 2^{nd} respectively which means that the preconditions for the tourism and excursion activity, development of pilgrimage and religious tourism, creation of a competitive tourism product with tour presentation within the CRTR are rather acceptable. The city of Lviv, manifesting absolutely different values and linkage closeness as possessed by all other regional units, requires its own unique strategy of management of sacral HCMs in the quality of the seventh cluster.

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Biogeochemical peculiarities of accumulation of chemical elements by plants of the Svydovets Massif of the Ukrainian Carpathians

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Abstract. The objective of the paper was determining biogeochemical peculiarities of accumulation of chemical elements (Mn, Ni, Co, V, Cr, Zr, Cu, Pb, Zn, Ba, P) by wild-growing shrubs (stems and leaves) – bog bilberry (*Vaccinium uliginosum)*, European blueberry (*Vaccinium myrtillus L.)*, alpine juniper *(J. communis subsp. alpina);* perennial herbaceous plants (flowers and leaves) – common tormentil (*Potentilla erecta (L.) Hampe*), willow gentian *(Gentiana asclepiadea*), true sedges *(Carex);* and trees (needles) of European silver fir *(Abies alba)* on nine plots in the Svydovets Massif of the Ukrainian Carpathians. The results we obtained based on field surveys (selection of samples of soil and vegetation) and interpretation of their analysis allowed us to determine the total regional background of chemical elements in soils and ash of plants using emission spectral analysis. We assessed the total concentration of chemical elements in soils of the plots (least to highest): the Apshynets Ridge – the Herashaska Polonyna – Drahobratske Lake – the Svydovets stream – Apshynets Lake – Herashaske Lake – the Zhuravlyne Bog – Vorozheske Lake (group of small lakes) – Vorozheske Lake (large) and determined the dependence on type of soil and pH. We determined that for wild-growing herbaceous plants the biogeochemical activity of species increases in the following sequence: true sedges - willow gentian - common tormentil; for wild-growing shrubs (bog bilberry, European blueberry, alpine juniper) such a sequence is impossible to determine due to the great difference between the values on different plots. We determined the role of each plant as medicinal for treating microelement deficiency in Cu, Zn, Co. We determined that in the plot of the Herashaska Polonyna, the needles of alpine juniper contain a maximum amount of Zn and Co, the needles and leaves of bog bilberry – Cu, Zn, Co; the flowers and leaves of common tormentil by Apshynets Lake and European silver fir near the area of the Svydovets stream – Cu. We calculated the daily dose of each element according to species of plants to overcome microelementosis. The results of biogeochemical surveys may be the basis for determining and recommending plants as medicinal, and also of geochemical and biogeochemical monitoring studies.

Key words: biogeochemical peculiarities. The Svydovets Massif of the Ukrainian Carpathians, accumulation of chemical elements, soils, vegetation, microelementosis

Біогеохімічні особливості накопичення хімічних елементів рослинністю Свидовецького масиву Українських Карпат

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Анотація. Метою роботи є виявлення біогеохімічних особливостей накопичення хімічних елементів (Mn, Ni, Co, V, Cr, Zr, Cu, Pb, Zn, Ba, P) дикорослою рослинністю: кущі (стебла та листя) – лохина (*Vaccinium uliginosum*), чорниця (*Vaccinium myrtillus* L.), ялівець сибірський (*Juniperus communis subsp. alpina*); багаторічні трав'янисті рослини (квіти та листя) – перстач прямостоячий, калган (*Potentilla erecta* (L.) Hampe), тирлич ваточниковий (*Gentiana asclepiadea*), осока (*Carex*); та дерев (хвоя) ялиці білої (*Abies alba*) на дев'яти ділянках Свидовецького масиву Українських Карпат. Результати отримані авторами на основі польових робіт (відбору зразків ґрунту та рослинності), та інтерпретаційної їх обробки дозволили визначити валовий регіональний фон хімічних елементів у ґрунтах та золі рослинності за допомогою емісійного спектрального аналізу. Оцінено сумарну концентрацію хімічних елементів у ґрунтах ділянок (від меншого до більшого): хребет Апшинець – полонина

Герашаська – озеро Драгобрацьке – потік Свидовець – озеро Апшинець – озеро Герашаська – болото Журавлина – озеро Ворожеське (група малих озер) – озеро Ворожеське (велике) та з'ясовано залежність від виду ґрунтів та рН. Встановлено, що для дикорослих трав'янистих рослин біогеохімічна активність виду зростає в ряду: осока – тирлич – перстач; для дикорослих кущів (лохина, чорниця, ялівець сибірський) такий ряд неможливо визначити, зважаючи на великий перепад значень на різних ділянках. Визначена роль кожної рослини, як лікарської в якості подолання мікроелементозного дефіциту Cu, Zn, Co. Встановлено, що на ділянці полонина Герашаська гілки ялівця сибірського вміщують максимальну кількість Zn та Co, гілки та листя лохини – Cu, Zn, Co; квіти та листя перстача оз. Апшинець і ялиця біла ділянки потік Свидовець – Cu. Розрахована добова доза кожного елементу за видами рослини для подолання мікроелементозу. Результати біогеохімічних робіт можуть стати базою при визначенні та рекомендації рослин як лікарських, а також моніторингових геохімічних та біогеохімічних досліджень.

Ключові слова: біогеохімічні особливості, масив Свидовець Українських Карпат, накопичення хімічних елементів, ґрунти, рослинність, мікроелементоз

Introduction.

Biogeochemical studies of the highland belt of the Svydovets Massif of the Ukrainian Carpathians are especially valuable as the gold standard for the region. The remoteness of the Massif from the industrial centers gives us reasons to suggest the ecologically pristine states of the flora.

Among well-known studies on determining the geochemical constituent of environmental objects, we have to note the following research (Kabata-Pendias, Pendias, 1989), (Alekseenko, 2000), (Samofalova, 2009), (Lang, Kruger, Chmara, 2017), (Kryuchenko, Zhovinsky, Paparyga, 2019) which is of high precision due to use of more advanced analytical methods.

For the territory of Ukraine, an important issue is assessing natural or technogenic geochemical anomalies, and in order to do so in the first place it is necessary to determine the regional background content of chemical elements in soils and vegetation. The studies (Klos, Birke, Zhovinsky, 2012), (Zhovinsky, Kryuchenko, 2014), (Zhovinsky, Kuraeva, 2002) devoted to determining sources of anomalous content of chemical elements in soils and vegetation gave a new sense to the aspects concerning assessment of the anomalies.

Currently, there are very few studies on the biogeochemical condition of the Ukrainian Carpathians. The first studies on determining the chemical content of soils and vegetation of the Ukrainian Carpathians concerned the use of secondary aureoles and flows of diffusion of metallogenic provinces (Sushik, 1978). After these studies, materials on geochemical composition of the regions` environmental objects have not been presented for quite a while. As a result of complex study of geochemistry of the territory of the Carpathian Biosphere Reserve (CBR), the results were published of research (Zhovinsky, Kryuchenko, 2014) which included analyses of geochemical content of environmental objects, and results were presented of research on patterns of chemical elements and their mobile forms in soils, ground water and surface waters, vegetation, mushrooms and atmospheric precipitations (Zhovinsky, Kryuchenko, Paparyga, 2013). Further studies (Kryuchenko, Zhovinsky, Paparyga, 2018) performed in these regions focused on ore and technogenic geochemical anomalies (lithochemical, hydrochemical, atmochemical, biogeochemical) in the protected territories of the Ukrainian Carpathians.

Biochemical studies with ecological purpose are broadly conducted in different regions of the world. Recent studies (2017-2020), presented to the scientific community, concern different species of plants (Kudrevatykh, Kalinin, Alekseev, 2019) as bioindicators for assessment and monitoring of environmental contamination with heavy metals (Kryuchenko, Zhovinsky, Paparyga, 2019), their accumulation in agricultural plants (Hazrat., Ezzat, Ikram, 2019), ecological toxicology of microelements (Wang, Wu, Liu, Liao, Hu, 2017), ecological resistance, toxicity and bioaccumulation of heavy metals in the environmental objects (Buts, 2018), (Palutoglu, Akgul, Suyarko, Yakovenko, Kryuchenko, Sasmaz, 2018).

The biogeochemical research conducted by us hase practical importance. In spite of the fact that most plants of the Svydovets Massif are medicinal ones used not only as raw material for the pharmaceutical industry, but also by the locals as tinctures, decoctions, it has become necessary to determine the properties of these plants in solving the problems of microelement deficiency, which we emphasized in our work.

The objectives of the study were peculiarities of accumulation of chemical elements (Mn, Ni, Co, V, Cr, Zr, Cu, Pb, Zn, Ba, P) by wild-growing vegetation (shrubs – bog bilberry (*Vaccínium uliginósum)*, European blueberry (*Vaccinium myrtillus* L.*)*, alpine juniper *(J. communis subsp. alpina);* perennial herbaceous plants – common tormentil (*Potentilla erecta (L.) Hampe*), willow gentian *(Gentiana asclepiadea*), true sedges *(Carex)* and trees (coniferous) European silver fir *(Abies alba))* in nine plots in the Svydovets Massif of the Ukrainian Carpathians.

Materials and methods.

Materials for the studies were the samples of surface deposits (soils) and wild-growing plants (the stems and leaves) and trees (the needles) in nine plots of the Herashaska Polonyna (montane meadow) (hereinafter – the Herashaska Pol.), the Apshynets Range (hereinafter – the Apshynets R.), Apshynets Lake (hereinafter – Apshynets L.), Herashaska Lake (hereinafter – Herashaska L.), the Zhuravlyne Bog (hereinafter – the Zhuravlyna B.), Drahobratske Lake (hereinafter – Drahobratske L.), Vorozheske Lake – large (hereinafter – Vorozheske L.), Vorozheske Lake – a group of small lakes (hereinafter – Vorozheske L. s.), the Svydovets stream (hereinafter – Svydovets s.).

The authors of the article collected the samples of soils and vegetation during the period of August-September of 2019. The criteria for selection of phyto-objects for geochemical testing were their ubiquitousness in the places of complex geochemical sampling (samples of vegetation were taken in the places of sampling the surface deposits). In total, 120 samples of soil and 150 samples of vegetation (around 25 samples of each species) were collected. The species of plants the samples were collected from are presented in Fig. 1.

Quantitative general chemical analysis of soils and ash was performed on a Saturn-3 spectrograph with graphite furnace in the Chemical-Analytic Center of the M.P. Semenenko Institute of Geochemistry, Mineralogy and Ore Formation of the National Academy of Sciences of Ukraine (analysts – V. I. Kolomiets, O. A. Zhuk). Sensitivity of analyses for different elements equaled 0.01 μg/dm^3 to 0.0001 μg/dm^3.

Analytic studies. Due to the absence of anthropogenic contamination of the studied territory, which is thanks to most of its area being under protected status, we used the following parameters to assess the soils (Alekseenko, 2000): coefficient of concentration (Kc) – ratio of actual content of chemical element to background content and total indicator of concentration (ΣKc) which equals the total of coefficients of concentrations of separate elements.

During the study of vegetation, we used such a parameter as coefficient of biological absorption (Ax) which equals the ratio of the content of the element in the ash of plants to its content in soil the plant lives in. To quantitatively express the general ability of species to concentrate microelements, we used the parameter of biogeochemical activity of species (BCA) which is

bog bilberry
(*Vaccínium uliginósum*)

european blueberry
(*Vaccinium myrtillus)*

alpine juniper *(J. communis subsp. alpine)*

common tormentil
(*Potentilla erecta*)

willow gentian
(Gentiana asclepiadea)

true sedges (*Carex sp.*)

european silver fir
(Abies alba)

Fig. 1. Species of plants of the Svydovets Massif, from which we took the samples

the total amount of coefficients of biological absorption (Ax) of separate microelements (Kudrevatykh, Kalinin, Alekseev, 2019). Statistical data analysis was performed using Statistica 10 software.

Characteristics of the areas of studies.

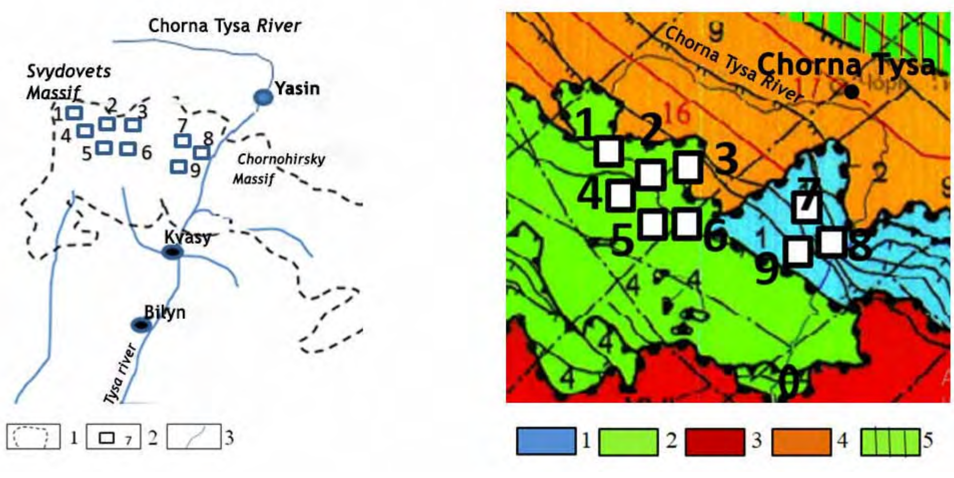
All sites were located within the Svydovets Mountain Massif – between the Teresva River (in the west) and the Chorna Tysa (in the east). This structure is one of the system-forming elements of the Ancient-Glacial high polonynas (montane meadow) of flysch landscapes of the Ukrainian Carpathians (Gerenchuk, 1981). It is characterized by slightly wavy lines of the mountains without sharp transitions between the saddles and peaks. According to the altitude level, it is the highland of the Ukrainian Carpathians located above the natural upper border of the forest (1,300–2,061m above sea level), covered by Alpine and Sub-Alpine vegetation on mountain alkaline-brown and mountain peat-brown soil (Vovk, Orlov, 2014).

According to the tectonic division, the surveyed sites belong to the Chornohirsky and Dukliansky nappes (Suschik, 1978) composed of Cretaceous and Paleogenic flysch and are different from each other in the structures of flysch deposits and some morphological peculiarities of the folded and rupture dislocations. Sites 1-6 are located within the Chornohirsky nappe, sites 7–9 – the Dukliansky nappe (Fig. 2).

The surveyed plots were identified as belonging to the high-mountain (1,400–1,700 m) altitude belt of the Ukrainian Carpathians. The high altitude zone of the mountains, located above 1,400 m, with its cold excessively humid climate and shrub-meadow vegetation is distinct in its highly idiosyncratic soil processes. The influence of rich herbaceous vegetation has resulted in the development of a peat type of soil formation, but biological life of the soil in such severe climatic conditions is less active than in the plains. Specific mountain-meadow-brown soils have been formed, the soil-forming rocks for which were the deposits sedimented over the period from the Lower Cretaceous to the Eocene. The soils are represented by rough-rhythmic flysch – with dominance of sandstones and fine- or average-rhythmic flysch – distinctive alternation of sandstones and clayey schists (Gerenchuk, 1981). In the process of weathering of these rocks, mostly loamy deposits form. The genetic profile of brown mountain-meadow soils is as follows: the layer of dead dry semi-humid 2-6 cm-deep meadow litter, humus horizon measuring 8-12 cm, of grey-brown colour, with well manifested grainy-fine nut structure, which together with debris of the parent rocks conditions the dryness and favourable aqua-air regime of brown earths (Zhovinsky, Kryuchenko, Paparyga, 2013). The rocks on which the brown mountain-meadow soils form are extremely poor in calcium compounds. Thus, they are poorly saturated with cations of two-valent metals and highly acid. Furthermore, the type of soil (sandy, sandy-loamy, loamy and clayey) corresponds to migratory properties of chemical elements (Table 1).

Results and discussion.

To determine peculiarities of uptake of chemical elements by plants, one needs to know their content in the soil. We determined the content of Mn, Ni, Co,



a *b*

Fig. 2. Scheme of locations of the plots in the study on the plan a): 1 – borders of the protected massifs of the Carpathian Biosphere Zapovednik , 2 – study plots and their numbers: 1 – Apshynets L., 2 – Vorozheske L. l., 3 – Vorozheske L. s., 4 – Herashaska L., 5 – the Apshynets R., 6 – the Herashaska Pol., 7 – the Svydovets s.; 8 – Drahobratske L., 9 – the Zhuravlyna B.; б) the tectonic scheme (Matskiv, Pukach, Vorobkanych, Pastukhanova, Hnylko, 2009): 1 – the Chornohirsky nappe; 2 – the Dukliansky nappe; 3– the Porkuletsky nappe 4 – the Krosnenska zone, 5 – Ivano-Frankivsk Oblast.

Table 1. Characteristics of survey plots in the Svydovets Massif

Number (according to Fig.1)	Name of the plot	Height (m a.s.l.)	Type of soil, pH	Samples of vegetation
1	Apshynets L.	1495	Clayey, pH 5,5–6,5	common tormentil, willow gentian
2	Vorozheske Lake L. l.	1450	Sandy-loamy and loamy, pH 4.5–6	alpine juniper
3	Vorozheske L. s.	1524	Sandy-loamy and loamy, pH 3.7–4.5	bog bilberry
4	Herashaska L.	1583	Sandy-loamy, pH 4.5–6	true sedges
5	Apshynets R.	1659	Sandy-loamy, pH 5.3–6.5	European blueberry
6	Herashaska Pol.	1633	Sandy-loamy, pH 4.9–6	bog bilberry, alpine juniper
7	Svydovets s.	1133	Loamy, pH 6.5–7	European silver fir
8	Drahobratske L.	1400	Loamy, pH 5.5–6	willow gentian, true sedges
9	Zhuravlyna B.	1470	Loamy, pH 3.7–4.5	alpine juniper

Ti, V, Cr, Mo, W, Zr, Hf, Rb, Ta, Cu, Pb, Ag, Sb, Bi, Zn, Cd, Sn, Ge, Ga, Be, Sc, Ce, La, Y, Yb, Th, As, Ba, Li, P, but only the group comprising Mn, Ni, Co, V, Cr, Zr, Cu, Pb, Zn, Ba, P was analyzed, because the content of other elements in ash of plants was lower than analysis sensitivity. For each plot, we determined the average content of the abovementioned elements, and determined the average content for all the plots (Table 2).

Comparing the average content of chemical elements with Clarke number of soils around the world, we determined: Ba, Pb – concentration in soils of the Massif exceeded average values 1.7–1.9; Co, Cr, Ni was 10 times lower; Mn, V, Cu, Zr –twice as low; Zn, P – almost the same. Such content of the elements is related to the regional geochemical background of Ca-poor soils.

To assess the soils of the Svydovets Massif, we determined the background content of chemical elements, making further calculations according to this parameter. We determined that concentrations of Mn, Ba, P were twice as low as the background regional content in all the plots, whereas in the plots of Vorozheske L. l. and Vorozheske L. s. the concentrations exceeded it by two times. This is related to the fact that the soils in the plots of Vorozheske Lake are sandy-loamy and loamy, significantly moistened, i.e. as the level of hydromorphism heightens, the amount of microelements in them increases as well. At the same time, in the conditions of regular outwash regime, metals are driven away from the profile of soils (the Apshynets R.), leading to decrease in their total content. Having calculated the concentration coefficient (Kc), we determined the distribution of chemical elements in the surveyed soils concerning the background content: the Apshynets R. $(Pb, Zn, Ba, Cr)_{0,5}$; the Herashaska Pol. $(V, Cr, Zn, Ba, P)_{0,5}$; Drahobratske L. $Zn_{1,5}>Cu_1$, Apshynets L. $(Pb, Zr, Co, V, Cr)_1$, the Svydovets s. $(Pb, Zn, Ba, Cr)_{1,5}>(Cu, P)_1$, Herashaska L. $(Pb, Zr, Cr, V, Co)_1$, the Zhuravlyna B. $(P, Co, Ni)_2>Cu_1$, Vorozheske L. l. $(Mn, Ba, Cr, Zr, Cu, Ni, Co)_2>(Pb, Zn, P)_1$, Vorozheske L. s. $(Mn, Ba, Cr, Zr, Cu, Ni, Co)_2>(Pb, Zn, P)_{1,5}$. This allowed us to determine that maximum concentration of all chemical elements is characteristic of the plots of Vorozheske L.

The optimum indicator for comparing geochemical peculiarities of non-contaminated soils is the total concentration coefficient (ΣKc). Calculation of this parameter allows us to calculate the total concentration of chemical elements in soils of the plots (from lower to highest): the Apshynets R. – the Herashaska Pol. – Drahobratske L. – Svydovets s.– Apshynets L. – Herashaska L. – the Zhuravlyna B. – Vorozheske L. s. – Vorozheske Lake L. (Fig. 3).

We determined that with increase in pH from 4 to 7, the total concentration of chemical elements decreased (23 to 4). When the plots were identical according to the type of soil – brown mountain earth, it was related to the type of soil – in case of loamy types (the Vorozheske lakes l. and s.), there occurred concentration of chemical elements, while in sandy-loamy ones (the Apshynets R. and the Herashanska Pol.) – dispersion.

Biogeochemical survey. Biogeochemical surveys were made according to chemical composition of parts of plants (Table 2), and their interpretation by calculating coefficients of biological absorption (Ax) and biogeochemical activity of species, allowed us to determine the overall effect of accumulation of microelements in the plants and determine the

Table 2. Total content of microelements in soils and ash of vegetation of the Svydovets Massif, mg/kg

Chemical elements	Numbers of the plots (according to Fig.1, Table. 1)									Background in the region	Clarke number of soils around the world [1]
	1	2	3	4	5	6	7	8	9		
	soils										
Mn	100	500	600	200	80	100	100	150	60	210	850
Ni	10	40	60	10	5	8	10	5	40	21	40
Co	3	5	6	3	1	1	2	1	5	3	8
V	30	80	80	40	20	10	30	10	20	36	100
Cr	30	80	100	40	20	10	30	10	10	37	200
Zr	200	400	400	300	80	100	100	100	60	193	300
Cu	10	80	80	10	10	10	40	20	30	32	20
Pb	20	25	18	18	15	18	12	8	12	16	10
Zn	20	50	50	20	20	20	20	50	20	30	50
Ba	100	300	200	100	90	90	100	100	100	131	500
P	200	500	500	200	200	200	400	200	500	322	800
	vegetation										
Mn	600	400	5000	5000	5000	4000	5000	500	5000	3389	7500
Ni	10	50	5	6	50	80	80	4	30	35	50
Co	2	6	2	1	6	10	8	1	4	4	15
V	3	3	2	3	5	6	2	5	4	4	61
Cr	3	6	5	2	5	5	5	5	5	5	250
Zr	10	20	20	30	30	20	40	20	30	24	5
Cu	30	80	80	20	50	60	100	30	60	57	200
Pb	1	10	10	4	6	20	5	5	6	7	10
Zn	50	100	100	50	100	400	100	100	100	122	900
Ba	100	500	600	300	100	300	400	100	100	278	100
P	10000	10000	8000	3000	10000	8000	10000	8000	10000	8556	70000

Note. Species of plants (plots – numbers of the columns, according to Table 1.): 1– willow gentian, 2– alpine juniper, 3 – bog bilberry, 4 – true sedges, 5 – European blueberry, 6 – alpine juniper, 7 – European silver fir, 8 – true sedges, 9– alpine juniper

main differences in intensity of involvement of microelements in biological circulation by different species of plants (Table 3).

We determined that wild-growing shrubs (bog bilberry, European blueberry, alpine juniper) actively absorb Mn, P and intensely absorb Co, Cu, Zn, Ba from the soils (except the plots of Vorozheske L. l. and the Vorozheske L. s., which is explained by presence of loamy soils, where it is hard for the roots of plants to adjust the element into available form. Herbaceous plants actively and intensely accumulated Mn, P, Cu. It is noteworthy that only in the Herashaska Pol. did the wild-growing shrubs - bog bilberry and alpine juniper concentrate Mn, P, Zn, Ni, Co, Cu. On that plot, there are sandy-loamy, moistened soils. In such conditions, chemical elements turn into a form which is available to plants.

We may draw a general conclusion that all the plants (regardless of growing location) actively and intensely absorb P and Mn, and furthermore the element which common tormentil accumulated was Cu, alpine juniper concentrated Zn, European silver fir – Ni, and for bog bilberry, European blueberry, willow gentian and true sedges the crucial role was played particularly by the growing location (composition of soils, pH).

It was important to determine the extent of uptake of metals Ni, Co, Cu, Zn, Ba, Pb by one type of vegetation at different plots, and therefore we compared and developed graphs for visual evidences (Fig. 4).

The obtained data indicate that wild-growing shrubs (bog bilberry, European blueberry, alpine juniper) are characteristic of intense biological uptake of Ni, Co, Cu, Zn, Ba, Pb, though in the plot of the Herashaska Pol., Zn was the element of active consumption (Ax equaling 20–25) by bog bilberry and alpine juniper. As for herbaceous plants, Ax value for all the

Table 3. Coefficients of biological accumulation in (Ax) and biogeochemical activity (BCA) of different species of plants in the Svydovets Massif

Name of the plot	Elements of biological accumulation (Ax)		Elements of biological absorption (Ax)	BCA
	active	intense	average	P Mn, Cu, Zn, Ba, Ni, Co, V, Cr, Zr, Pb, Bi
	10n і більше	10– n	0, n	
Wild-growing shrubs				
bog bilberry				
The Herashaska Pol.	$Mn_{50}>P_{40}>Zn_{25}>(Ni, Co, Cu)_{10}$	Cr, Pb, Ba	V, Zr	153,1
Vorozheske L. s.	P_{16}	Mn, Cu, Zn, Ba	Ni, Co, V, Cr, Zr, Pb	31,1
European blueberry				
The Apshynets R.	$Mn_{60}>P_{50}>Ni_{10}$	Co, Cu, Zn, Ba	V, Cr, Zr, Pb	141,2
The Svydovets s.	$(Mn, P)_{20}$	Zn, Ba	Cu, Ni, Co, V, Cr, Zr, Pb	47,7
alpine juniper				
The Zhyravlyne B.	$Mn_{83}>P_{20}$	Cu, Zn, Ba	Ni, Co, Pb, V, Cr, Zr	114,2
Vorozheske L. l.	P_{20}	Ni, Co, Cu Zn, Ba	Mn, V, Cr, Pb	28,4
The Herashaska Pol.	$(Mn, P)_{40}>Zn_{25}>(Ni, Co)_{10}$	Cu, Pb, Ba	V, Cr, Zr	132,5
Herbaceous plants				
common tormentil				
Apshynets L.	$Mn_{50}>P_{50}>Cu_{10}$	Zn, Ba	Ni, Co, V, Cr, Zr, Pb, Bi	115,7
willow gentian				
Drahobratske L.	P_{50}	Mn, Ni, Co, Cu, Bi, Zn, Ba	V, Cr, Zr, Pb	71,1
Apshynets L.	P_{50}	Mn, Ni, Cu, Zn, Ba	Co, Pb	64,5
true sedges				
Herashaske L.	$Mn_{25}>P_{15}$	Cu, Zn, Ba	Ni, Co, Pb, V, Cr, Zr, Bi	48,8
Drahobratske L.	P_{40}	Mn, Co, Cu, Bi, Zn, Ba	Ni, V, Cr, Zr, Pb	51
Trees				
European silver fir				
Svydovets s.	$Mn_{50}>P_{20}$	Cu, Zn, Ba	Ni, Co, V, Cr, Zr, Pb, Bi	99,5

elements equaled 1–5, the exception being common tormentil in the plot of Apshynets L., where consumption of Cu equaled 10. The extent of uptake of chemical elements by European silver fir in the plot of the Svydovets s. was 1–8: Ni>Zn>Ba>Co>Cu>Pb. We should take into account that this chemical element composition of plants which grow in the protected territories may be an etalon for comparison with other plants.

Regardless of the growing location, herbaceous plants - true sedges (Herashaske L., pH 4.5, Drahobratske L., pH 6.3) and willow gentian (Apshynets L., 4.5 and Drahobratske L., pH 6.3) have close values of BCA: true sedges – 47–49, willow gentian – 64–71, common tormentil – 115. For wild-growing shrubs (bog bilberry, European blueberry, alpine juniper), BCA significantly varied. Therefore, BCA of alpine juniper was 28.4 at the Vorozheske L. (l), whereas in the Herashaska Pol. it was 132.5, i.e. 4 times greater. Bog bilberry of Vorozheske L. (s.) was seen to have BCA of 31.1, whereas in the Herashaska Pol. it equaled 153.1; for European blueberry it was 47.7 in the Svydovets s., and 141.2 in the Apshynets R.; BCAs of alpine juniper were similar in the Zhyravlyna B. and the Herashaska Pol. equaling 114.2 and 132.5 respectively, while accounting for 28.4 at Vorozheske L.(l.). As for the trees, BCA of European silver fir was 99.5. We can see that for herbaceous plants, there is a BCA sequence of true sedges–willow gentian– common tormentil. For wild-grow-

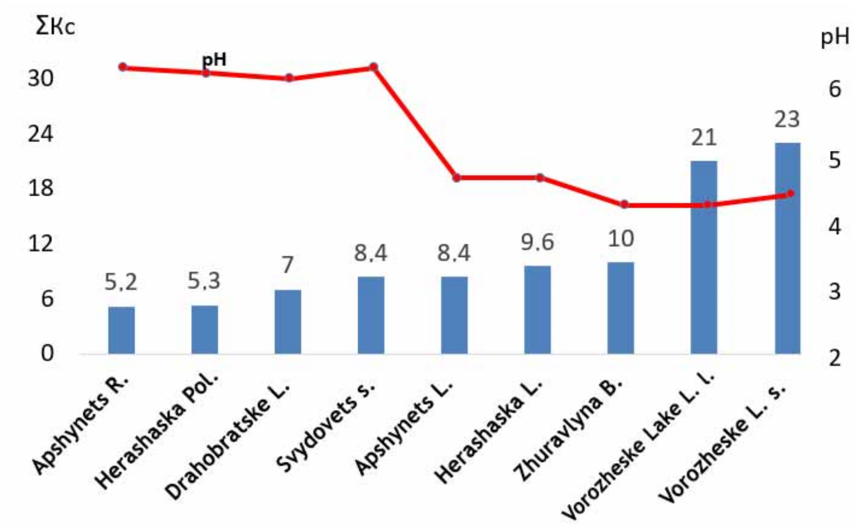


Fig. 3. Diagram of values of the total concentrations coefficient (ΣKc) of chemical elements (Mn, Ni, Co, V, Cr, Zr, Cu, Pb, Zn, Ba, P) and pH of soils in the study plots

ing shrubs, the sequence is impossible to determine according to BCA due to large differences between the values for various plots.

Microelements. Specificity of the element composition of plants determines the possibility of their use as medicinal raw material. The plants we examined are used in folk medicine (Yakovlev, 2015). For example, one of the most important properties of bog bilberry (berries, leaves) is the ability to mitigate allergy, it has anti-atherosclerotic and anti-ulcer effects; European blueberry (berries and leaves) has antioxidants which affect malignant tumours, cleanses the intestines from salts and metals; common tormentil is used for treatment of dysentery, abscess, hemorrhoids,

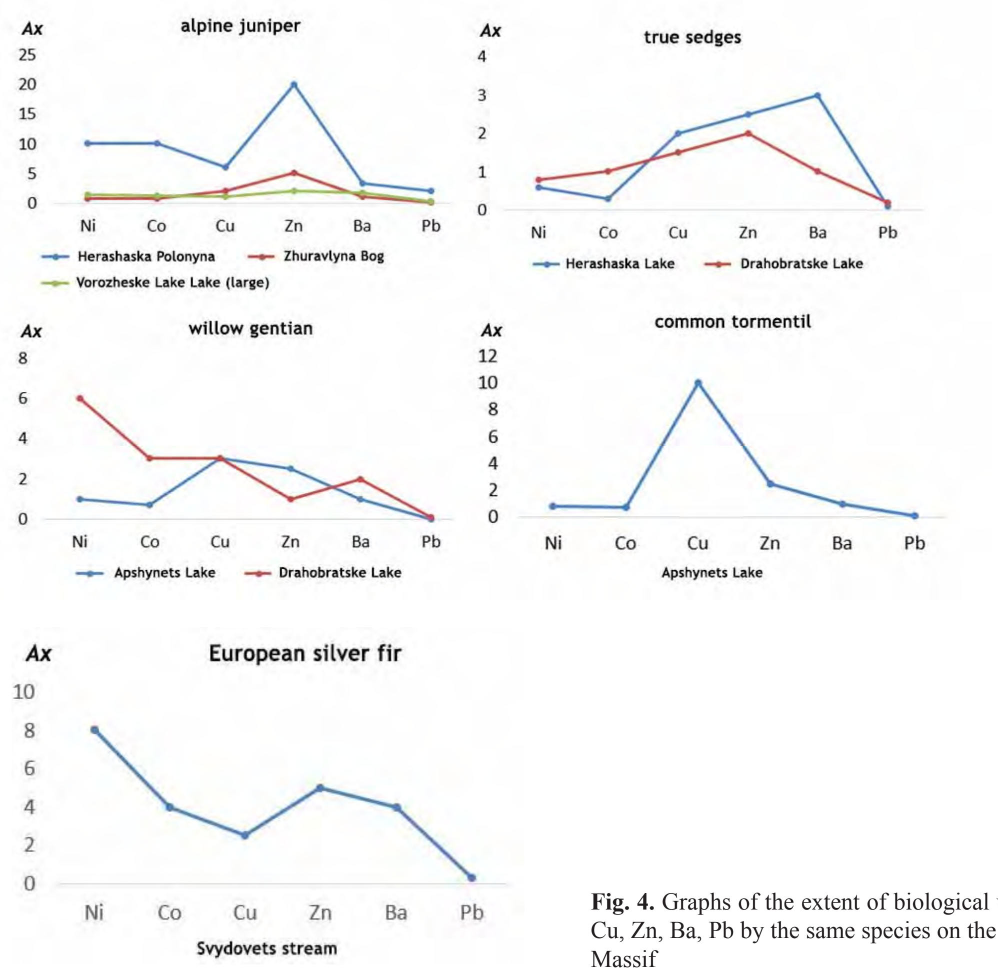


Fig. 4. Graphs of the extent of biological uptake (Ax) of Ni, Co, Cu, Zn, Ba, Pb by the same species on the plots of the Svydovets Massif

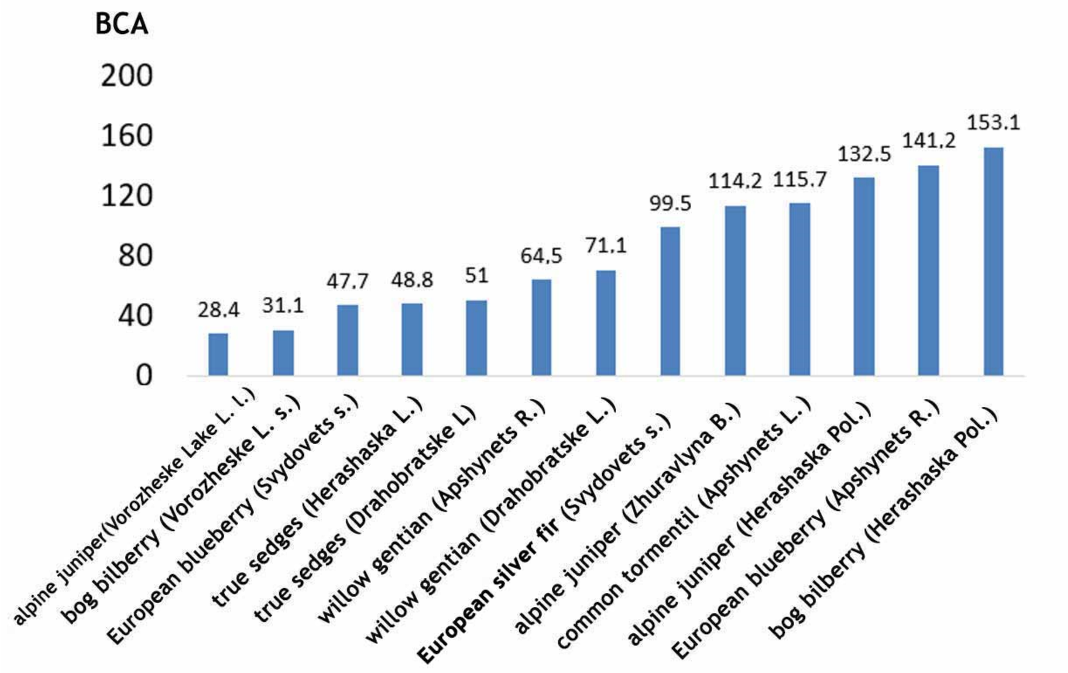


Fig. 5. Diagrams of biogeochemical activity of plants (BCA) in the plots of the Svydovets Massif

has bactericidal, binding and blood-stopping properties, because it reduces penetrability of the capillaries and narrows the vessels; willow gentian has antiseptic, anti-parasitic, diuretic properties; alpine juniper is used to obtain essential oil from the fruits, branches and needles, has toning, generally strengthening, anti-inflammatory, expectorant effect; true sedges are used as diuretic, anesthetic, anti-inflammatory preparation; European silver fir – tincture of needles removes accumulated harmful substances from the organism, is used to treat diseases of the respiratory tracts, strengthening the immune system.

However, a special role in the normal functioning of all physiological systems of the organism belongs to microelements contained in at least 2,000 enzymes which catalyze many chemical reactions in the organism. Deficiency, excess or dysbalance of microelements is called microelementosis (Bardov, 2006). Microelement correction in contemporary practical medicine is becoming more and more popular among people who are convinced of the vital necessity of replenishing deficiency in microelements for successful treatment of patients.

We analyzed the content of microelements – Zn, Cu, Co in plants of surveyed plots for possibility of recommendations concerning their balance in the organism.

Zinc. The daily need of a human for zinc is 12-16 mg for adults and 4-6 mg for children (3). The largest amount of zinc among food products is seen in groats: buckwheat – 14.9 mg/kg, wheat groats – 13.7 mg/kg; in vegetables: garlic – 6.7 mg/kg, beet – 3.9 mg/kg (Ivanov,1994). Deficiency of zinc is accompanied by growth retardation, over excitement of the nervous system and rapid onset of fatigue.

We determined that the zinc concentrators are the plants in the Herashaska Pol. - alpine juniper and bog bilberry – 400–500 mg/kg (at background – 60 mg/kg), whereas the amount of zinc in these plants in the plots of the Vorozheske L. l. and the Vorozheske L. s. was equal– 70 mg/kg (Fig. 6 a).

We calculated the conditionally sufficient norm for supply of the zinc balance (plants of the Svydovets) for one adult per day: 30 g of bog bilberry would be needed from the Herashaska Pol., and 160 g from Vorozheske L.; as for alpine juniper – 40 g of the plant from the Herashaska Pol., while 160 g of the ones from the Vorozheske L.

Copper. Daily copper requirement of the adult organism is 1.5 mg (Bardov, 2006). In plant products the content of copper is 1–10 mg/kg: buckwheat groats – 6.4 mg/kg, oat groats – 5 mg/kg, walnuts – 7.5 mg/kg, beans – 6.8 mg/kg (Ivanov,1994).

Copper content in plants of the Svydovets Massif varied insignificantly: lowest was seen in true sedges and European blueberry – 20–30 mg/kg, in willow gentian and alpine juniper it accounted for 30–60 mg/kg; maximum – in bog bilberry, common tormentil and European silver fir, equaling 80–100 mg/kg (Fig. 6 b). Thus, the main role belongs to selectivity of plants regarding copper, while growing location is not significant. We estimated that for support of daily balance of copper of one adult, 20 g of bog bilberry, common tormentil and European silver fir, collected

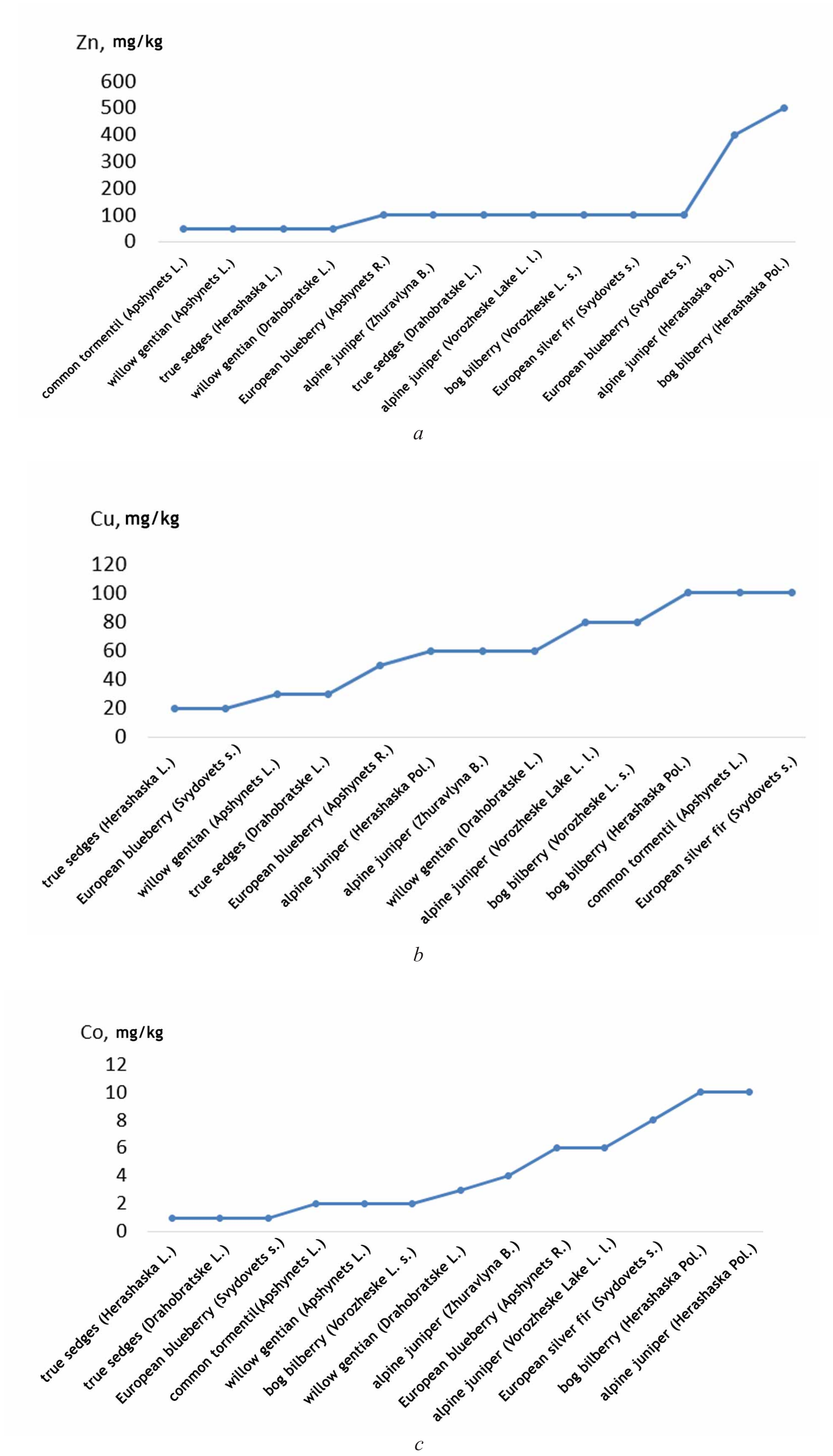


Fig. 6. Graphs of content of Zn, Cu, Co metals in plants of the plots of the Svydovets Massif

from any plots on the Svydovets Massif are needed, whereas other plants would be needed in amount of 70–100 g.

Cobalt. The content of cobalt in plants of the Svydovets Massif slowly increased from true sedges (Herashaske and Drahobratske lakes) – 2 mg/kg to alpine juniper and bog bilberry of the Herashaska Pol. – 10 mg/kg (Fig. 6c). For the Heraska Pol., sandy-loamy soil was typical, pH 4–6, and these conditions were optimum for accumulation of cobalt by plants.

Cobalt is a constituent of vitamin B12, the content of which in the human organism reaches 5 mg. The daily requirement for cobalt is 0.1-0.8 mg (Bardov, 2006). Cobalt content in plant products, mg/kg: walnut – 0.15; beet – 0.12 mg/kg; strawberry – 0.9 mg/kg (Ivanov, 1994). By calculating the norm of cobalt for one adult, we determined that 30 g of alpine juniper and bog bilberry from the plot of the Herashaska Pol. would be needed, while other plants would be needed in the amount of 100–300 g.

Finally, we would like to note that correction of microelement deficiency using plant supplements needs to be performed individually, considering specifics of the organism.

Conclusions.

The research allowed us to find biogeochemical properties of uptake of chemical elements (Mn, Ni, Co, V, Cr, Zr, Cu, Pb, Zn, Ba, P) by wild-growing vegetation (shrubs, herbaceous plants and trees – European silver fir) on nine plots of the Svydovets Massif of the Ukrainian Carpathians. We determined the background content of chemical elements and estimated the total concentration of chemical elements in soil plots (from lowest to highest): the Apshynets R. – the Herashaska Pol. – Drahobratske L. – the Svydovets s. – Apshynets L. – Herashaske L. – the Zhuravlyna B. – Vorozheske L. l. – Vorozheske L.s. The soils in the plots of Vorozheske L were found to be sandy-loamy and loamy, highly moistened, i.e. their reserves of microelements increase following increase in the level of hydromorphism. At the same time, in the conditions of periodic wash-out regime, the metals are driven away from the soil profile (the Apshynets R.), and thus their overall content decreases. We determined that the extent of the influx of the elements to plants depends on the overall content of the elements in the soil. Using the coefficient of biological absorption, we determined that all the plants (regardless of their growing location) actively and intensely absorbed P and Mn from the soils, for common tormentil the element of accumulation was Cu, alpine juniper – Zn, European silver fir – Ni; for bog bilberry, European blueberry, willow gentian and true sedges the important factor was growing location (composition of soils, pH of environment). We determined that for wild-growing herbaceous plants the biogenic activity of species increases in the sequence: true sedges– willow gentian– common tormentil; for wild-growing shrubs (bog bilberry, European blueberry, alpine juniper) such a sequence is impossible to determine in spite of great differences between different plots. We determined the medicinal role of each plant to treat microelement deficiency in Cu, Zn, Co. We determined that on the plot of the Herashaska Pol. the branches of alpine juniper contain maximum amount of Zn and Co, the branches and leaves of bog bilberry – Cu, Zn, Co; the flowers and leaves of common tormentil from Apshynets L. and European silver fir near the Svydovets s. – Cu. We determined the daily dose of each element according to species of plants to overcome microelementosis. The results of the studies on biogeochemical peculiarities of accumulation of chemical elements by vegetation of the Svydovets Massif of the Ukrainian Carpathians may be the basis for identification and recommendation of plants as medicinal, and also monitoring geochemical surveys to predict the use of plants to overcome microelementosis among the population.

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A model for the development of high quality training of tourism professionals through the use of computer 3D-tours

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Abstract. The article is focused on the problem of training future tourism specialists using informational and communication technologies. The educational process of preparation requires changing the educational and methodological support in order to give the students the opportunities to master modern professional tools, technologies, methods of creating high quality tourist products. To solve this problem, the authors propose a model for the development of high quality training of tourism professionals through the use of computer 3D-tours. The development of this model took into account the theoretical and methodological basis regarding the professional training of future specialists in the field of tourism, the results of the analysis of educational programs, curricula for training students of the speciality "Tourism" and the data of the pilot experiment. It consists of the following main blocks. The conceptual-oriented block includes concepts, approaches, principles of participation, information and communication technologies. The content-technological block includes the content of the educational project of developing 3D-tours, levels of professional knowledge and skills, as well as types of familiriazation with ICT tools. The educational content of the model takes into account the practical mastery of the student's professional skills in the development of various 3D-tours. During this process, the ICT tools are introduced gradually in a certain order. The organization-activity block of the model includes forms of organizing the study and technologies for studying. This model entails the involvement of classroom-based and remote, individual, and group forms of organization of the educational process, organization of project development for a detailed analysis of educational topics. The assessment-resultative block includes criteria, metrics and levels. During the development of the model, the results of the activity of the subjects of the educational process were analyzed in accordance with two groups of criteria: the criterion of formation of professional theoretical knowledge, practical skills of 3D-tour development and the criterion of the level of using modern software and technical means in creative educational development. The developed model allows for increasing the quality of training of future tourism specialists. During the practical application of the proposed model, virtual 3D-tours were developed. Their development has shown the possibility of implementing the model of development of training of specialists in tourism by using computer 3D-tours with the use of modern ICT tools in the study of special disciplines and the attaining professional skills.

Keywords: virtual tour, tourism, development model, concepts, approaches, future specialists.

Модель розвитку якісного навчання фахівців з туризму шляхом використання комп'ютерних 3D-турів

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Анотація. Стаття присвячена проблемі підготовки майбутніх фахівців сфери туризму з використанням інформаційно-комунікаційних технологій. Навчальний процес підготовки потребує змінювати навчально-методичне забезпечення, щоб надати студенту можливість засвоювати сучасні професійні засоби, технології, методики створення якісних туристичних продуктів. Для вирішення зазначеної проблеми, авторами запропоновано модель розвитку якісного навчання фахівців з туризму шляхом використання комп'ютерних 3D-турів. Розробка даної моделі передбачала врахування теоретико-методологічних положень щодо професійної підготовки майбутніх фахівців сфери туризму, результатів аналізу освітніх програм, навчальних планів підготовки студентів спеціальності «Туризм» і даних пілотажного експерименту. Вона складається з таких основних блоків. Концептуально-цільовий блок включає концепції, підходи, принципи участі, принципи інформаційно-комунікаційних технологій. Змістовно-технологічний блок включає зміст навчальної проектної розробки 3D-туру, рівні сформованості професійних знань та умінь, а також типи ознайомлення з засобами ІКТ. Навчальний зміст моделі враховує практичне оволодіння студентом професійних умінь розробки різноманітних 3D-турів. При цьому залучається поступовість у використання засобів ІКТ, що реалізується за рахунок побудови відповідної послідовності. Організаційно-діяльнісний блок моделі включає форми організації навчання та технології навчання. Дана модель передбачає залучення аудиторних та дистанційних, індивідуальних, групових форм організації навчального процесу, організації проектної розробки для детального розгляду навчальних тем. Оцінювально-результативний блок включає критерії, показники та рівні. В ході розробки моделі аналізувалися результати діяльності суб'єктів навчального процесу за двома групами критеріїв: критерій сформованості професійних теоретичних знань та практичних умінь розробки 3D-туру та критерій рівня застосування сучасних програмних та технічних засобів в творчій навчальній розробці. Розроблена модель дозволяє підвищити якість навчання майбутніх фахівців з туризму. Практичне застосування запропонованої моделі дозволило розробити віртуальні 3D-тури. Їхня розробка показала можливість реалізації моделі розвитку навчання фахівців з туризму шляхом використання комп'ютерних 3D-турів із застосуванням сучасних засобів ІКТ в ході вивчення спеціальних дисциплін та формування професійних умінь.

Ключові слова: віртуальний тур, сфера туризму,модель розвитку, концепції, підходи, майбутні фахівці

Introduction.

The level of development of computer technologies at the current stage allows for enlarging the possibilities of presenting objects of tourism, and posting them on the Internet, at the same time providing opportunities for interactive effects. Thanks to interactive effects, whole informational systems can be created inside one panorama, supplementing it with video material, animation, sound, informational windows and menu, and also various special effects, for example reflections of the sun depending on the scene which is being observed. In turn, a virtual 3D-tour is a set of such panoramas, between which one can move using special areas on the panorama. A single click of the mouse on such point or area brings the effect of going to another panorama or object. All this provides unique possibilities of producing virtual tours to well-known places, museums and galleries with complete integration into virtual reality.

Currently the system of higher professional education of future specialists in the sphere of tourism is oriented toward development of the student as a future professional with professional competence, high spiritual culture, learning flexibility, the ability to navigate through the novel achievements of science and practice, high level of development of moral-ethical qualities and professional ethics. In such conditions, requirements to the formation of individual qualities of specialists in the sphere of tourism significantly increase (Cherezova, 2013).

The educational process of training future specialists in the sphere of tourism requires changes in the educational-methodological base in order to provide the student with opportunity to master the professional tools, technologies, methods of creating high-quality tourist products. At the same time, the traditional process of education cannot entirely meet the current requirements to education of future specialists. The educational process needs introduction of novel approaches of innovative development of tourism, new information-communication technologies and formation of a pedagogic environment, aimed at organizing favourable conditions for education in the modern information environment.

While researching the education of specialists in tourism by using computer technologies, we used conceptual provisions of touristic education and professional preparation of specialists in tourism (I. Zorin, V. Kvartaliov, L. Knodel, A. Konoh, V. Fedorchenko); scientific works on the problems of helping future specialists in attaining the required professional level (I. Havrysh, K. Durai-Novakova, M. Diachenko, L. Kandybovych, O. Kucheriavy, A. Lynenko); scientific research on the problems of effective use of information technologies in tourism (H. Haluzynsky, M. Yefremova, M. Zhelieni, A. Levkova, S. Melnychenko, H. Papyrian, M. Skopen, T. Tkachenko, F. Ullaha, M. Hammera); studies on the problems of introduction and determination of the main purposes, goals and perspectives of virtual technologies in the tourism business (Z. Hadetska, V. Shamlikashvili, O. Sporysh, M. Bahrov, O. Shablii, L. Melnyk and others). At the same time, we determined that the problem of education of specialists in tourism by using computer 3D tours in scientific papers remains unanalyzed. The relevance of solving these issues conditioned the selection of the topic of our research and determined its objective and goal.

Objective of the paper is scientific substantiation of the theoretical-methodological base and practical provisions of development of technological and management solutions regarding improvement of the pedagogic system of preparation of specialists in the tourist sphere by developing a model of high-quality education using computer 3D tours. Based on this research, we determined an optimum model of development of high-quality education of specialists in tourism, which would help improve the process of acquisition of knowledge of the material studied and automatization of the process of control and analysis of student activity, performance of academic tasks, and also provision of distant practical and module tasks.

Materials and methods of studies.

For the purposes of the development of high-quality education of future specialists in the sphere of tourism, we constructed a model of high-quality education of specialists in tourism by using computer 3D tours. In order to achieve the goal of the study, we used the following methods:

- Analysis of philosophical, psychological-pedagogic and scientific-methodological literature (to determine the problem of professional preparation of specialists in the sphere of tourism);
- Generalization and systematization (to determine the essence of the notion “virtual tour”);
- Systemic-structural analysis (to classify the contemporary professional means and describe the pedagogic conditions of their implementation);
- Complex analysis (to determine the tendency of training specialists in the tourist sphere);
- Analytical and comparative methods (to study contemporary trends in using computer 3D tours);
- Processing approach (to present the mechanisms of the development of high-quality education of specialists in tourism by using computer 3D tours);
- Program-purpose approach (to determine goals during drawing of the model of development of high-quality education of specialists in tourism);
- Systemic analysis and synthesis (to develop conceptual basis of the development of high-quality education of specialists in tourism);
- Methods of modeling and projecting (to create the model of development of high-quality education of specialists in tourism);
- Graphic and cartographic methods (to visualize the image of start windows of developed 3D tours).

Results and their analysis.

A virtual tour is a sequence of several connected panoramic photos, between which in the process of viewing one may visually navigate through using special transitions, and interact with the objects included in the image for additional information. In other words, a virtual 3D tour is a means of projecting a realistic image of three-dimensional multi-element space on the screen (Hadetska, 2014).

A 3D tour (virtual tour) unites several 3D-panoramas interconnected by several references – points of transition between each other, interactive map of the area, means of navigation of panorama in one style. Also, the panoramas may include Flash animation, sounds and noises. By moving from one three-dimesional object to another, you can go straight into the action, see objects and interiors, people who surround you, while remaining at one’s workplace at the computer.

A virtual tour is an effective tool of marketing which allows the potential consumer to see the goods or services in a special way. It creates “the effect of presence” for the viewer – bright memorable visual images, thus providing the fullest possible information on goods or services. Virtual tours and panoramas are some of the most efficient and persuasive ways of providing information today (Hadetska, 2014).

Virtual tours have a number of advantages over other commercial and information means. Virtual tours are actively displacing such broadly applied means of media advertizing as presentation and videos. All this is possible due to the simplicity of the development of such novel technologies, reduction of time between the tour and the familiarization of the buyer with it, simplicity and speed of posting new tours, and updating and replacing old virtual tours, which is a guarantee of relevance of the presented information. The cost of virtual tours is lower, while the efficiency is higher as compared to that of video.

The main advantages of virtual tours are as follows:

Possibility of saving time, both for the party which presents the tour (seller) and for the buyer (potential buyer or client);

Increasing the interest in the tour itinerary, object or tour company;

Increase in prestige of the tour objects, and therefore attraction of new clients;

Increase in revenues of the companies.

Disadvantages of virtual tours are

Complexity of required knowledge and skills for the development of such types of tour;

Difficulty of asking questions while viewing the tour;

Lack of emotions, low level of memorizing;

Quality of tour depends on developers (professional skills of developers are the main factors of quality of touristic products);

High cost of creating services for the client;

May be viewed only on electronic devices (Kravchenko, Sushchenko, 2018).

Professional preparation of future specialists in the sphere of tourism is the process whereby students gain special knowledge, practice and skills, work experience, which help to raise highly professional specialists in the sphere of tourism (Kobzova, 2013).

Students who study the Speciality 242 Tourism study a large number of disciplines, including “Informational systems and technologies”, “Management of projects in tourism”, “Information systems and technologies in tourism”, “Analysis of activity of touristic enterprises”, “Innovation technologies in tourism”. We analyzed typical programs of special disciplines for training future specialists in the sphere of tourism and distinguished the following generalizing requirements to the speciality-related competence:

- Awerness of contemporary tendencies and regional priorities of development of tourism in general and its separate forms and kinds;
- Abilities to develop, promote, implement and organize the consumption of the tourist product;
- Understanding principles, processes and technologies of organization of work of the subject of the tourist industry and its subsystem;
- Ability to monitor, interpret, analyze and systematize tourist information, ability to present tour informational material;
- Ability to use information technologies and office equipment in the work of tourism enterprises;
- Ability to determine individual needs using modern technologies which provide services to tourists;
- Ability to co-work with business partners and clients, ability to effectively communicate with them;
- Ability to create specialized tourism products and organize services to tourists.

Based on the research performed, we built a model of development of high-quality education of specialists in tourism by means of using computer 3D tours (Fig. 1).

While developing such a model, we took into account theoretical-methodological provisions concerning preparation of future specialists in the sphere of tourism, results of analyses of curricula, educational plans of training students of the Tourism speciality and data of the pilot experiment. Using means of information-communication technologies in the study of specialized disciplines would help:

Increase effectiveness of grasping the material;

- Automatize the process of control and analysis of students` activity, performance of academic tasks, and also provide remote execution of practical and module tasks;
- Develop the student`s independence in performing typical tasks, self-assessment and self-analysis with remote checking of the stages of execution and final academic result by the teacher;
- Build professional skills in using ICT in development of tourist products;
- Build information-communication competence in students, modern professional skills in using and operating means of ICT, professional software and innovatory technical means.

Education with use of information-communication technologies in higher education institutions may be organized according to the level of coverage:

- At the level of the educational institution;
- At the level of a structural unit (subunits) of the educational institution;
- At the level of speciality of training;
- At the level of cycle of educational disciplines;
- At the level of separate educational discipline (Borysenko, 2018).

Depending on the level of organization of education, we may distinguish the structure which would include informational, program, and technical resources, methodological provision, and also create additional structural units for technical support. At each level, there are individual peculiarities of informational content, organization of communication and achievement of result.

The model of development of high-quality education of specialists in tourism by using computer 3D tours is based on the concepts of Smart City, sustainable development of tourism, innovatory development of tourism, educement, scientific concept, 3D visualization, decomposition of 3D models, problem-oriented, creative approaches, correspondence of current requirements to the labour market, social orientation of tourist preparation.

We consider the proposed model as a theoretical construct of the corresponding process of preparation during teaching special disciplines. It is an integrity of interrelated structural blocks oriented toward developing students` attainments in using computer 3D tours: conceptual-oriented (the main concepts, approaches and principles of organization of education which influence the use of computer 3D tours are determined), content-technological (the student

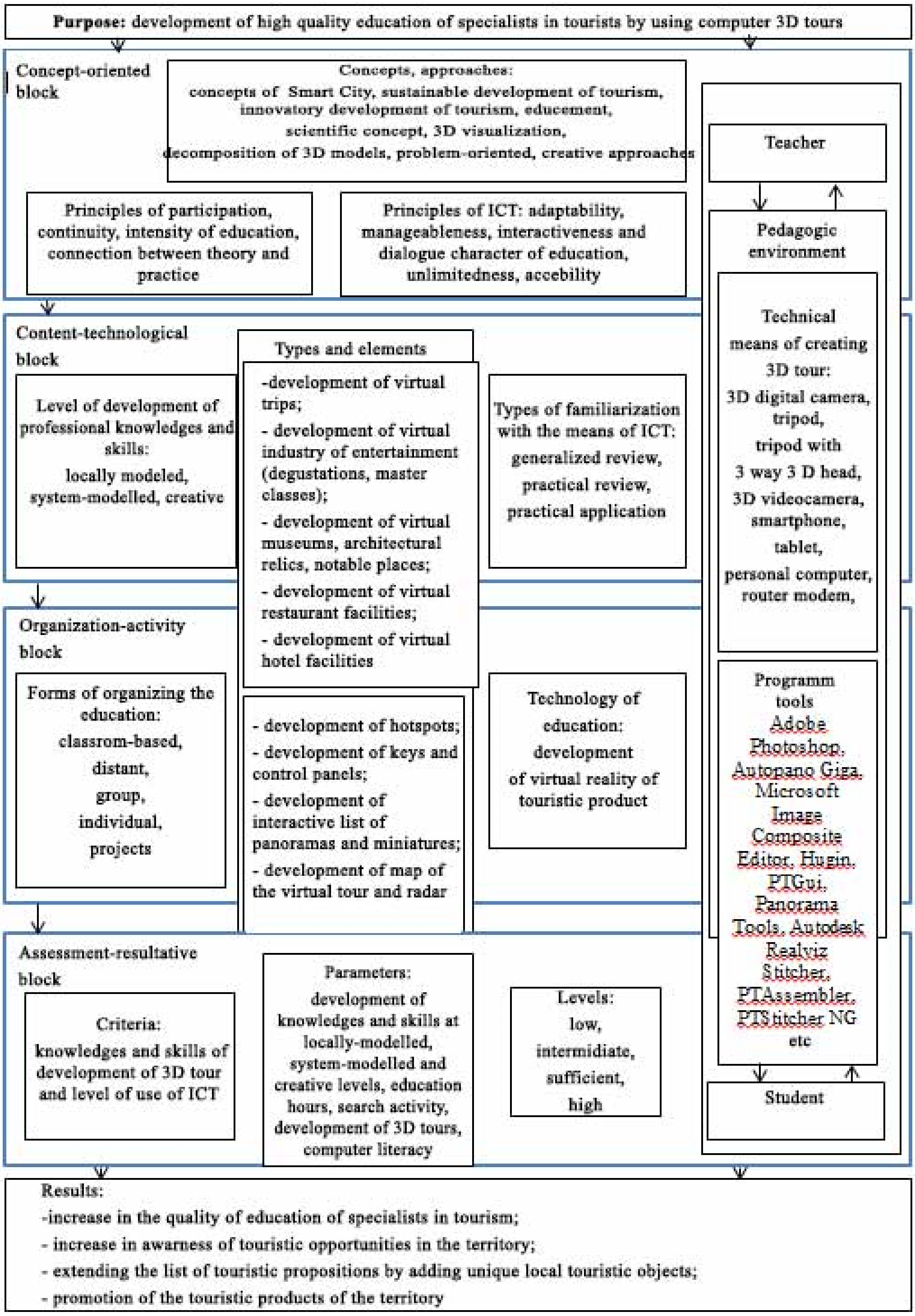

Fig. 1. Model of development of high-quality education of specialists in tourism by using computer 3D tours [developed by the authors]

becomes aware of the content of academic project development of the 3D tour, types of educational purposes, taking into account the levels of professional knowledge and skills, types of familiarization with the means of ICT), organization-activity (involvement of forms of organizing study and specifics of implementating education technologies based on the development of virtual reality of the tourist product), assessment-resultative (includes students attaining the corresponding level of readiness to use computer 3D tours).

The concept-oriented block includes concepts, approaches, principles of involvement, information-communication technologies. The method of development of education of specialists in tourism by using computer 3D tours was implemented with consideration of the following concepts of tourism: "Smart City" (efficient integration of physical, digital and human systems in an artificial environment for the purpose of providing a sustainable, successful and all-round future for citizens), sustainable development of tourism (system of views in the sphere of tourism which help orientatation in the use of virtual environment and create new 3D products, consideration of historical experience of using media means in the sphere of tourism, directions and styles), innovatory development of tourism (introduction to the market of improved services of people's intellectual work , which have new consumption qualities, which shall in some time become an object for new improvements, to the market. The goal of the innovation in the sphere of tourism is increase in satisfaction of clients as a factor of heightening their quality of life), educement (content of education and organization of obtaining knowledge through various forms of organization and self-organization for meaningful recreation. A high level of education which progresses in its development with active involvement in tourism is a trait of the new epoch of social development, therefore introduction of such a type of education in preparation of specialists in tourism, in our opinion, is possible by the means of using 3D tours), approaches: scientific (analysis of views of scientists and researchers on the possibilities of using the advantages of a virtual environment, priority directions of use in pedagogic communication), 3D virtualizations (possibilities of contemporary technological trends concerning their use in the educational process for visualization of information), decomposition of 3D models (replacing solution of a large task with solving series of smaller tasks, although not interrelated, but simpler), problem-oriented (formulation of problem tasks and situation), creative (establishing education while taking into account the creative development of students) approaches.

The model takes into account the didactic principles of: participation (direct involvement of students in creating virtual media in the process of search activity), continuity (systemic and systematic repetition of the studied material in logically complete parts – modules), intense study (communicative goal of study becomes reality, therefore purpose-oriented and resultative technology of education develops), relationship between theory and practice (emphasizing importance of practical study, consolidation of acquired theoretical knowledges in the process of practice), as the main fundamentals of training future specialists in tourism.

Consideration of the specifics of using ICT first of all concerns the parameters of adaptivity (adapting the computer to individual peculiarities of future specialists in tourism), manageability (the tutor can correct the process of making 3D product at any moment), interactivity and dialogue character of study (information-communication technologies can "respond" to the actions of students and teachers, "become involved" in dialogue with them), unlimitedness (content, its interpretation and additions are quite large), availability (provision of open access to gaining competence in using the resources of means of ICT).

The content-technological block includes the content of educational project development of the 3D tour, levels of professional knowledge and skills, and also types of familiarization with the means of ICT. Educational content of the model includes professional practical skills of the student in development of various 3D tours. At the same time, the means of ICT are learned gradually according to the following sequence: development of virtual trips; development of virtual industry of entertainment (degustations, master classes); development of virtual museums, architectural relics, notable places; development of virtual restaurant facilities; development of virtual hotel facilities, development of hotspots; keys and control panels; interactive list of panoramas and miniatures; development of a map of the virtual tour and radar. Educational content will be presented in the educational program and detailed for each academic task in the methodological recommendations for performance of practical tasks. During the study, one should take into account three levels of professional knowledge and skills: locally modeled, system-modelled, and creative. They include the transition from the apprehension of knowledge to testing the thinking. At the same time, at the first, local-modeling, level, the student is able to effectively solve didactic-methodological tasks in order to achieve the goal – develop the 3D product, as much as possible taking into account the real educational situation, using the novel achievements of modern science. At the second, systemic-modeling, level, the student is supposed to be able to model the individual trajectory of development of the product using the means of problem-search methods of study which correspond to the needs, motives and interests of the future specialists in tourism. At the third, creative, level, the student should have thorough knowledge of the professional sphere, generate new concepts, organizes activity in non-typical situations.

During the training of future specialists in tourism, the following types of familiarization with the means of ICT are studied: generalized review and practical review and practical application. At the same time, the students become gradually familiarized with the software and technical means. At the first stage, the generalized review, the students go over the properties of the software or apparatus capacities and then gradually proceed to practical application of them for particular tasks. During practical review, the students integrate more into working with software or technical devices, becoming familiarized with the complete list of functions and possibilities, its practical application for solving professional tasks. Practical application is characterized by dynamic involvement of the program or technical device, its professional use with already planned results using instruments of software or parameters of the technical device.

The organization-activity block of the model includes forms of organization of education and technologies of education. The model of development of high-quality education of specialists in tourism by the means of computer 3D tours implies involvement of classroom-based and distant, individual and group forms of organization of the educational process, organization of project development for detailed analysis of the topics. The model is orientated to the development of virtual reality of the tourist product – implies virtual visits and viewing of especially interesting natural-, historic-cultural objects using the means of modern information-computer technologies and communications and the Internet in any point of the space in online regime. The elements of virtual tourism are virtual excursions and virtual tours, which in the contemporary tourist management are effective tools of attracting the potential tourist or guide to really visit the objects of these excursions/tours (Biletskyi, Kotyk 2019).

Such products are interesting to operators and hotels which promote a certain touristic direction or particular place of recreation. A 3D tour helps the tourist more simply understand what to expect in the journey. During the virtual tour, he would feel the real dimensions and atmosphere of the place, walk along the beach or swim in coral reefs, therefore knowing exactly where to go afterwards.

The assessment-resultative block includes criteria, parameters and levels. During the development of the model, we analyzed the results of activity of subjects of the educational process according to two groups of criteria: the criteria of professional theoretical knowledge and hands-on skills in developing 3D tours and the criteria of the level of applicability of the contemporary program and technical means in creative educational development.

The first level and criterion of professional theoretical knowledge and practical skills of development of the 3D tour is the level of understanding of the 3D tour and its further creation. In the process of study, specialists in tourism begin to acquire the first understanding of the 3D tour, and implement this understanding. The subsequent level in achieving the goal is studying technologies of making the product. While studying, specialists in tourism construct special knowledge and skills sufficient for the functions of the first level of professional activity for creating the tour. The final, the main level is mastering the special disciplines, which is characterized by attainment of individual professional abilities, development of creative and individual abilities which are necessary to create a virtual tour, and constant interest is manifested in this program product.

The criteria of the level of application of contemporary software and technical devices in creative academic development allow the specialists in tourism, during study of special disciplines, to raise their level of skills in computer technologies and technical devices; based on the algorithm of creating 3D tour, to formulate a creative approach to use of the elements to solve a given task and individually create a 3D tour.

According to the group of criteria, the corresponding parameters were formed for each level of knowledge, professional skills, expenditure of educational time, search work, development of 3D tours, computer literacy, and also the influence of the elements of the methodological system on the formation of interest and activity, practical resultativeness and use of contemporary software and technical devices.

Parameters should be evaluated according to corresponding levels of professional skills, distinguishing low, average, sufficient and high. The division should be made based on an accumulative (range) system of assessment corresponding to the results of performing academic tasks.

Organizing lessons in special disciplines requires creating an information environment where the following elements would be used complex combination :

Communication devices:

- Email (the most common technology of sharing information on the Internet, not only for entertainment and social needs, but in the professional sphere as well – analyses of stages of development of the 3D tour, remote development of technical documentation and its analysis, etc);
- Blog (web-site with broad or limited access which allows one to interact with its authors in comments);
- Virtual board (interactive remote tool of

communication of teacher with students, which may be also used in the future professional sphere to organize the process of making 3D tours);
- Social networks (active instrument of up and running contact between participants of discussion which implements not only information sharing, but through which it is possible to development social status, as well as using them as a presentational tool) and others;

Information means:
- Traditional office set of programs and apps (their use is not limited by the use of already installed functionalities, but may additionally demonstrate new elementary ways of development of a 3D tour, design of creative ideas, simple graphic interface of the search, analysis of 3D tours and development of prototype);
- Software for analysis of image (various software allows for processing of photos and creating equiangular projections of panorama, i.e. combines images into one);
- Software for graphic design of tour (their use allows addition of active zones into a panorama, developing graphic design of the tour, if needed, adding sound, pop-up windows with text, etc).
- Division into informational and communication means is specific, because the representatives of communicative means allow not only transfer, but creation of information content in complex with additional software (on-line and off-line apps) (Bilushchak, Paslavska, Reut, Rudnyk, 2016). Also, these means include additional technical devices for analysis, presentation and making of 3D tours (3D digital camera, tripod with 3-way head, 3D video camera, smartphone, tablet, PC, router modem, multiplexor, etc). Mastering them is the main goal of methods of education of specialists in tourism.
- The general structure of the pedagogic environment of use of computer 3D tours in education of future specialists in tourism can be usefully presented in the following steps:
- Lectures concerning mastering theoretical generalized material from the special discipline;
- Lectures that familiarise students with the means of ICT they may use;
- Practical mastering of the means of ICT during practical lessons;
- Obtaining thematic object for academic task;
- Performing academic tasks using technical and software means of ICT;
- Achieving educational results and implementing them practically.

At first, one may use traditional classroom-based presentation of the material, which may have a distant format of exchange of information content between the teacher and students through developed program systems, universal models and shells, or ways specially designed by the teacher. The main goal of the remote variant is creating conditions for providing high-quality preparation by giving students an opportunity to attain fundamental or additional knowledge of information-communication technologies. This variant is important for the extramural form of education, when there is increased education load on teacher and other cases. For full time students, classroom-based study is the dominant form. Moreover, for raising the motivation component, the teacher enriches the traditional forms with innovatory specifics of organization, contemporary technical means, developed electronic support in the form of multimedia lecture-conspectuses, web apps, etc.

The next stage is familiarizing students with contemporary technical resources and other means of ICT, which shall be used to perform academic tasks. These means have broad universal application, as well as specific professional orientation. Among the technical means used are 3D digital camera, tripod, tripod with 3D head, 3D videocamera, smartphone, tablet, personal computer, modem router, multiplexor. Availible software would include Adobe Photoshop, Autopano Giga, Microsoft Image Composite Editor, Hugin, PTGui, Panorama Tools, Autodesk Realviz Stitcher, PTAssembler, PTStitcher NG, etc.

While familiarising future specialists in tourism with the means of ICT, the teacher emphasizes the available range of software and certain software products for academic tasks due to specific peculiarities, the simplicity of quick mastery, professional use and other criteria.

During the analysis of typical programs for special disciplines “Information systems and technologies”, “Mangement of projects in tourism”, “Information systems and technologies in tourism”, “Analysis of activities of tourism enterprises”, “Innovatory technologies in tourism”, we determined inter-subject connections with other educational programs of disciplines: “Geography of tourism”, “Recreational complexes of the world”, “Organization of tourism”, “Organization of tourist trips”, etc.

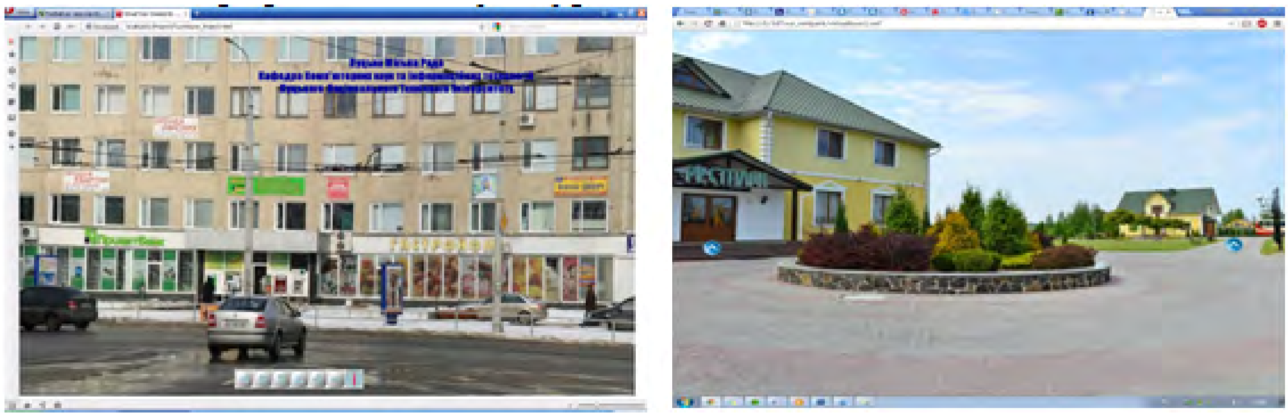

Fig. 2. View of start windows of developed 3D tours – "Virtual Lutsk" and Recreational Complex "Restpark"

The process of development of virtual tours included several stages:

- Selection of the number of points (panoramas) in virtual tour;
- Development of individual menu and additional interactive functions;
- Taking photos of the object;
- Composing the 3D panorama and virtual tour;
- Posting on the web-site and testing.

In order to form the required tourist products, we conducted studies of the expedience of their introduction to selected tourist objects. Accordingly, during the lessons in the discipline "Innovatory technologies in tourism", we developed the following virtual 3D tours (Fig. 2):

- "Virtual Lutsk";
- "Recreational Complex "Restpark",
- Center of Traditional Culture "Medova Hata".

The virtual excursion "Virtual Lutsk" was developed using PTGui, Microsoft Image Composite Editor, Tourweaver 5 Professional Edition programs. To develop the virtual tours "Recreation Complex RESTPARK" and "Center of Traditional Culture "Medova Hata", we used a complex of software tools, namely Kolor Autopano Giga, PanotourPro and Adobe Photoshop.Those program products have a friendly, intuitively understandable interface, and also allow the achievement of impressive results in a relatively short time (although the latter is possible only if ideal photographs are stitched into the panorama). Ultimately, development of the program product takes a minimum amount of time, whereas using other technologies achieving the same result would take a week of work by a team of developers. Virtual tours are launched through swf file, supported by almost all computers (Lepkyi, Podoliak, Kosheliuk, 2015).

To navigate through virtual 3D tours, a Help key was installed, which is located first on the right side. At any moment, the Help window may be opened.

Assessment of the mentioned tourist products was made by students during production and pre-diploma practice. The results of assessment met with a favourable response from consumers of tourist products, increasing the quality of educational program in the speciality "Tourism" by forming corresponding competences in learning.

Summming up our research, based on the said conceptual generalized provisions, we may note that realization of the model of development of education of specialists in tourism is possible by means of use of computer 3D tours with application of contemporary means of ICT during study of special disciplines and formulation of professional skills.

Conclusions.

The training of future specialists in the sphere of tourism in the use of computer 3D tours is a constituent of the general system of preparing specialists in the sphere and is considered as a process of acquisition of preparedness to perform this particular activity. To determine the structure of this process of training, we developed a model, which according to characteristics, is a total of interrelated structural blocks – concept-oriented, content-technological, organization-activity, assessment-resultative, oriented towards making students ready to create 3D tours. The presented model becomes a benchmark of developing the corresponding process of training in practice. Expedient directions of further studies include the identification and adaptation of special methods of high-quality education of students for efficient realization of the given model of development of high-quality education of specialists in tourism by means of using computer 3D tours.

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New data on geology of the Rybalsky Quarry, unique object of geological heritage of Global Significance

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Abstract. Among the great variety of geological relics of Ukraine, one of the most attractive is the Rybalsky Quarry, located in the city of Dnipro, and well known outside Ukraine. First of all, it is famous for the Mandrykivski Layers exposed in one of the ridges of the Quarry back in the 1970s, although there are many other important peculiarities of the geological structure of the Quarry which attract scientists from Ukraine, Germany, France, Netherlands, Russia and other countries. There are full data on the history of discovery and survey of the Mandrykivski Layers from their discovery by Valerian Domger in 1882 to current studies that reveal various aspects of geological structure of the Quarry, the results of study of different groups of fossil fauna, compare them with the fauna of the Paris Upper Eocene basin and other well-known locations. Particularly in the Rybalsky Quarry, thanks to the author`s efforts, the Layers received the status of "layers with geographic name", as confirmed by the decision of Cenozoic Commission of the National Stratigraphic Committee of Ukraine in 2001. New fragments of the section of subaerial and subaqueous deposits of the Quaternary deposits were found and their composition, structure and complete stratigraphic content were studied. The research allows us to consider it typical for the Middle Prydniprovia. Fluvioglacial and lake-glacial deposits of the Dnipro glaciations in the Quarry exposed for the second time in 25 years, but this is the first time when their genetic origin, position in the section and lithological-facies peculiarities were determined. Thick layer of sands embedded on the roof of the Mandrykivski Layers were identified to the fifth or Hadzhybeiska terrace of the Dnipro, in the upper part of which there were notable siliceous-clayey-ferruginous formations or lateral crust (ferruginous crusts). The studies of the layer of brown-green and red-brown clays in the roof of the Mandrykivski layers allows us to presume their marine origin. In this case, they are underwater weathering crust (terra rossa) developed in the process of halmyrolysis or are the product of dissolution of carbonate silt enriched with detritus of mollusks, corals and other inhabitants of the warm Mandrykivske Sea.

Key words: Rybalsky Quarry, Mandrykivski Layers, climatolite, loess, fossil soil, geosite, crust

Нові дані до геології Рибальського кар'єру – унікального об'єкту геологічної спадщини Світового значення

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Анотація. Серед великої кількості геологічних пам'яток України одним з найбільш привабливих залишається Рибальський кар'єр, розташований у місті Дніпро та добре відомий далеко за межами України. Перш за все завдяки мандриківським верствам, розкритих одним із уступів кар'єру ще у 70-х роках минулого століття, але, як з'ясувалося пізніше ще й чимало інших важливих особливостей геологічної будови кар'єру приваблюють дослідників з України, Німеччини, Франції, Нідерландів, Росії та інших країн. Наведено досить вичерпні дані стосовно історії відкриття і дослідження мандриківських верств від моменту їх відкриття Валеріаном Домгером у 1882 році до сучасних робіт, у яких висвітлюються різні аспекти геологічної будови кар'єру, результати вивчення різних груп викопної фауни, співставлення її з фауною Паризького верхньоеоценового басейну та з іншими відомими місцезнаходженнями. Саме в Рибальському кар'єрі, за клопотанням автора, верстви отримали статус «верств із географічною назвою», що підтверджено рішенням комісії кайнозою Національного стратиграфічного комітету України у 2001 році. Виявлено та досліджено нові фрагменти розрізу субаеральних і субаквальних відкладів четвертинних відкладів, їх склад, будову і повну стратиграфічну наповненість, що дозволило вважати його типовим для Середнього Придніпров'я. У кар'єрі, вдруге за останні 25 років розкрито флювіогляціальні і озерно-льодовикові відклади часів дніпровського зледеніння, але вперше встановлено їх генетичну приналежність, положення у розрізі та літолого-фаціальні особливості. Доведено приналежність потужної товщі пісків, залягаючих у покрівлі мандриківських верств до п'ятої або хаджибейської тераси р. Дніпра, у верхній частині якої виразно проявилися кремній-глинисто-залізисті утворення або латеритна кіраса (феррікрети). Дослідження товщі буро-зелених і червоно-бурих глин у покрівлі мандриківсьих верств, дозоляє припустити їх морське походження. У такому разі вони являють собою підводну кору звітрювання (терра роса), утворену в процесі гальміролізу, або продукт розчинення карбонатного мулу, збагаченого детритом молюсків, коралів та інших мешканців теплого мандриківського моря.

Ключові слова: Рибальський кар'єр, мандриківські верстви, кліматоліт, лес, викопний ґрунт, геосайт, кіраса

Introduction.

The geological history of the territory of Ukraine is characterized by incredible diversity and contains almost the entire range of the stratigraphic scale – Precambrian to Holocene. Geodiversity creates respectively a large list of mineral deposits which are successfully extracted using various technical means. One of such methods is quarry, when not only ore rocks are extracted, but the landscape is damaged, causing ecological problems. At the same time, quarries are a great source of information about the geological structure of the fragments of the Earth`s crust inaccessible from the surface, their mineral and natural diversities, tectonics, etc. One of such quarries is the Rybalsky Quarry, located within the city of Dnipro and well-known outside Ukraine. The Quarry became famous in Europe because of the discovery of unique Upper-Eocene fossil faunas in the Mandrykivski layers. According to the diversity and stratigraphic value of the Paleogene, scientists consider that the Mandrykivska Fauna is inferior only to the Paris Basin. This, however, is not the Rybalsky Quarry`s only special attraction or highlight. Over the long period of extraction of granites in the Quarry, numerous evidence of geodiversity there has been found, which is analyzed in this paper.

Brief historical review.

The objective of this research was not the analysis of all the literature sources in one way or another related to the discovery and study of the Mandrykivska fossil fauna. Among a large circle of scientists related to this event, we have to mention the first and the most famous ones on one hand and the ones responsible for discovery of the Mandrykivski Layers in the Rybalsky Quarry on the other hand. And by the way not only the people related to the Mandrykivska Fauna itself, first found in the Quarry in 1977, but also the ones who discovered other peculiarities of geological structure of this part of the territory of the eastern slope of the Ukrainian Shield over the period of 40 years. The Layers with their unique fauna were first discovered by Valerian Domger in 1882 in the River Dnipro during drilling of borehole for the construction of the Katerynoslavsky Bridge (Sokolov,1894, 1905; Domger,1902). There were remains of fish, numerous shells of mollusks, spicules of sponges, fragments of corrals, Bryozoa, nummulites, etc. Preliminary analysis of diverse fossil fauna from glauconite sands allowed V. A. Domger to come to the conclusion that the layers which contain it, according to the deposition, correspond to Middle-Eocene, the so-called "coarse limestone" of the Paris Basin. It has to be noted that despite the fact that Rybalsky Quarry is near (4 km) the location, the lithological-facies conditions of formation of the deposits, in which the fauna of Eocene basin lived, significantly differed from those which are typical for the Quarry. This indeed explains the impoverishment of the forms determined by V. Domger in the area of the Monastyrsky Island compared with the later found localities where the fauna-containing rock was mostly detritus, poorly cemented by a small amount of sandy-clayey carbonaceous material.

Somewhat later, in 1886, during the digging of a well in the manor house of a German, A. A. Osvald, in Mandrykivska Sloboda (currently city Dnipro), a layer of sand oversaturated with very well preserved shells was discovered. A professor of Kharkiv University A. V. Hurov, to whom A. A. Osvald gave the collection in the same year, identified the Mandrykivski sands to the Eocene and considered its synchronous sands and sandstones those of Traktemyrivka and Buchak villages. In 1894, M. O. Sokolov, as allowed by A. A. Osvald, made a vertical trial pit in the yard of his manor house, obtained a sufficient amount of fossils and based on their identification he drew a conclusion that the age of detritus sands of the Mandrykivka is of the Low-Oligocene, corresponding to the period of accumulation of the Latdorf Stage in Germany. He thought that the closest to the Mandrykivski glauconite sands are those around Latdorf, Unseburg, Osterweddingen and other territories then described by Adolf von Könen. Later the fauna of the Mandrykivska Layer was surveyed by A. V. Faas (1894), P. A. Tutkovsky (1895), L. L. Ivanov (1914), V. S. Slodkevych (1933), who proved that the detritus sands of Mandrykivka village, the Monastyrsky island and the area near the railroad bridge of stations Merefa-Kherson are an integral stratigraphic layer. In 1931 B. F. Meffert studied the foraminiferans fauna from the Mandrykivski detritus rocks and stated that most species were found to be of the Eocene age. He draws attention to a large amount of Nummulites and Discocyclina and underlines their absence in the Oligocene. In 1939 L.F. Lungershausen for the first time proposed that the Mandrykivski Layers are shallow water facies of the Upper part of the Kyiv stage. Later this presumption was confirmed by numerous works by O. K. Kaptarenko-Chornousova on Foraminifera (Kaptarenko-Cheronousova, 1941, 1946, 1949).

In 1947 the Mandrykivski Layers in the area formerly owned by A. Osvald was studied by M. N. Kliushnikov. He came to a conclusion that the area of distribution of detritus lime-clayey sands with fossils on the outskirts of Dnipropetrovsk expands far beyond Mandrykivka village and provided in-detail data on new locations. A significant achievement in studying the Mandrykivka fauna was the study by N. N. Karlov, the results of which were reported in 1950. He was the first person after V. O. Domger who collected and analyzed the rich paleontological deposits from the Dnipro River near Shevchenko Park, but this time in the northern-western part of the Monastyrsky Island during the construction of foot- and automobile bridge. Interestingly enough, N. N. Karlov for the first time mentioned the diverse fossil fauna discovered in the core sample the borehole drilled during the exploration within the future Rybalsky Quarry (Karlov, 1950). The author compares the Layers with the light-green sands embedded on the Kyiv marl.

In 1954 M. V. Yartseva provided persuasive data on the Upper Eocene age of not only the known locations of the Mandrykivska fauna, but other places, significantly distant from them. A notable event in the history of studying the age of the layers was the identification of the Latdorf Sands in Germany to the Upper Eocene, based on studies by Krutzsch and Lotsch (Krutzsch & Lotsch, 1957). Complex study of deposits of the Mandrykivska fauna within Dnipropetrovsk was carried out by P. H. Nestereko, who provided the results in the book “Paleogenic sediments of the South European part of the USSR” in 1960 (Nesterenko, 1960), based on the analysis of a large amount of archive material (16 special borehole were drilled according to the profile which cross-sectioned the Dnipro in the area of Monastyrsky Island and included Mandrykivka village). M. V. Yartseva determined the complexes of nummulites from the core samples taken from the boreholes, the content of which allowed her to identify the deposits which contained them to the Upper Eocene (Jarceva, 1960). This is also confirmed by the content of mollusks extracted from the core samples from the borehols and identified by D. Y. Makarenko.

A new stage in studying the Mandrykivski Layers began with their exposure in the large area of the Rybalsky Quarry of extraction of granites for rubble and crushed stone. The Rybalske deposit of Precambrian crystalline rocks was for the first time explored in 1932. In the same year, the reserves of the natural stone for construction were approved in the amount of 4,029 thou m^3, followed by mining operation of the deposits. Later, in 1956, a geosurvey of the Quarry was performed by Filippeo and in 1962 by Baranov A. V. for the purpose of increasing the reserves. The year when the section of Paleogenic deposits was exposed in the Quarry is unknown, but the first visits to the Quarry in order to carry out scientific studies took place in 1977. The fauna of the Mandrykivska Layers in one of the ridges of the Quarry in its south-east part was first described in 1978 by paleontologists of the Scientific-Research Institute of Geology of the Dnipropetrovsk State University, including M. F. Nosovsky, I. D. Konenkova. I. M. Barg and Y. M. Bohdanovych (Nosovskyi, Konenkova, Barg, Bogdanovich, 1978). A large complex of nanoplakton was discovered, identical to the one E. Martini identified in 1970 studying the samples of the Mandrykivski Layers (Martini, 1970), and which corresponded to zone NP19. The composition of mollusks was also studied, revealing the presence of single and colonial corals, Ostracoda, small nummulites, Bryozoa, shark teeth. Apart from the Chaplynsky Quarry (mistaken name of the Rybalsky Quarry), the paper presents paleontological characteristic of some other deposits of the Mandrykivska Fauna located within Dnipropetrovsk, or currently Dnipro. These are bore holes bored in the territory of the Karl Liebknecht Plant and the Peremoha housing complex, the material from core samples of which, similarly to the collection of fossil fauna, has not been preserved. Therefore, the only outcrop of the Mandrykivska Layers has been and still is the Rybalsky Quarry.

In the same year 1977 and during the following years, the issue of stratigraphy and paleontology of the Mandrykivski Layers in the Rybalsky Quarry was researched by the scientists of the Dnipropetrovsk Mining Institute (currently National Technical University Politechnika). The problem of identification of the age of the Mandrykivska Fauna was studied by Veselov A. O., Shyrokov A. Z., Dyssa F. M. based on the research of material from the core samples from a specially drilled bore holes in Mandrykiva village and analysis of the literature sources and comparison to the Upper-Eocene Fauna from well-known deposits on Ukraine (Shirokov, Dyssa, 1972; Veselov,1972; Veselov, Golev, Lyulieva, Savenko, Sheremeta, 1974;

Chekunov, Veselov, Gilkman,1976). The results of the studies conducted by the authors in the Rybalsky Quarry were published in the reports of the Academy of Sciences of the USSR in 1986 and contributed to growth of interest in further study of the unique Mandrykivska Fauna (Shirokov, Veselov, Stefans'kij, Petrusha, 1986).

Gastropods of the Mandrykivski Layers of the Rybalsky Quarry have been thoroughly surveyed since 1977. The prominent Russian paleontologist O. V. Amitrov emphasized that the Mandrykivsky Complex attracts special attention not only because it exceeds all other well-known paleontological complexes in the richness and integrity of the fauna, but also because according to geographic position, the species composition and age, it is close to typical northern complexes (Latdorf, Tongrian, *Chegan*), and according to the composition of the families belongs to the intermediate type (Amitrov, 1986, 1987, 1996). Amitrov O. V. also considers that the Mandrykivski Layers are characteristic of faster spatial changes in the complexity, indicating that repeat collections in the old location and discoveries of new deposits with the same integrity may extend the lists of the Fauna. He found over 400 species of gastropods, belonging to 39 families (Amitrov, 1986).

V. L. Stefansky (since 1986) has been working on a monographic description of Bivalvia mollusks of the Mandrykivski Layers, taking into account the new rules of zoological nomenclature and systematics, for 35 years. His collection and analysis of one the best collections of mollusk fauna of Mandrykivka gave the author a reason to consider the Mollusca complex of the Rybalsky Quarry an etalon for Upper-Eocene deposits of the shallow water facies of the territory of Ukraine (Stefanskyi, 1987, 1992, 2013a,b, 2014, 2015a,b).

Berezovsky A. A., starting in 1990, has been systematically performing surveys on Paleogene Bivalvia within the Kryvy Rih iron ore basin and is one of the prominent paleontologists who are highly familiar with Bivalvia of the Mandrykivski Layers of the Rybalsky Quarry (Berezovsky, 2010, 2015). In 1994, based on his discovery of 14 species of Bivalvia mollusks in the deposits of the Inhulets Quarry, which he identified as Middle-Eocene ones, known in other regions of Europe only in the Upper Eocene deposits, he came to a conclusion that most mollusks of the Mandrykivski Layers of Ukraine and Latford Stage in Germany have appeared in the Lutetian (Berezovsky, 1994). Nanoplankton and dinoflagellates of the Mandrykivska Layers in the Rybalsky Quarry were studied by N. A. Savytska, who indicates the presence of a nanoplankton complex of *Discoaster saipantnsis* subzone and an impoverished complex of dinoflagellates of the zone of *Rhombodinium porosum*. She has also determined a complex of nanofossils of *Isthmolithus recurves* of the zone of *Discoaster barbadiensis* and complex of dinocysts of *Charlesdowniea clathrate angulosa.*

During our in-depth geological mapping of the Dnipro – Tomakivka interfluves, in the layers of the Paleogenic rocks, the presence of the Upper Eocene deposits was for the first time paleontologically substantiated, which became another evidence of the broadest distribution of Alma (Upper-Eocene) transgression compared with the Middle Eocene (Konenkova, Bogdanovich, Koralova, Manyuk, 1995; Manyuk, 1999). Earlier, the northern border of its distribution was indicated much further south of the water area of the Kahovka Water Reservoir. An important result of the paleontological surveys was designation of 4 complexes of microfauna, typical for the Alma and Obykhivka suites and the obvious similarity of one of them to the complex of the Mandrykivska Layers of the Rybalsky Quarry. Apart from foraminiferans, the complex contains mollusks, Ostracoda, Bryozoa, corals, Algae, spines of Echinoidea, and various nanoplankton. The conducted studies revealed that the Upper Eocene deposits in the area of conjunction of the Ukrainian Shield, Prychornomorska and Dnipro-Donetsk depressions have been developing under the influence of the warm-water Alma Basin, from where water with high content of silica inflows from the side of the Dnipro-Donetsk depression. This conclusion is confirmed by designation of four complexes of microorganisms, including the first and the second ones characterizing the Obukhivska Suite of northern Ukraine, and the third and the fourth – Alma Suite of northern Ukraine (Konenkova, Bogdanovich, Koralova, Manyuk, 1995).

Since 1998, the first articles concerning not only the Mandrykivski Layers of the Rybalsky Quarry, but also the Quarry`s geodiversity were published, thus presenting the quarry as a promising geological monument of nature (geosites) of European significance (Manyuk, 1998, 1999а,б, 2001а). The Rybalsky Quarry is indicated as a complex geological relic of nature (geosite) and deserves to be accredited with the status of object of the Nature-Reserve Fund of Ukraine (NRF). It has to be emphasized that it is the only Europe`s outcrop of the Mandrykivski Layers with unique Upper-Eocene fossil fauna, represented by various Bivalvia and Gastropoda mollusks, nummulites, foraminifera, ostracods, dinoflagellates, corals, Bryozoa, teeth of sharks, spines of Echinoidea (Manyuk, 2001a,b; 2002a,b,c,d; 2003a,b).

Of great significance in paleontological study of the Mandrykivski Layers in the Rybalsky Quarry were the surveys by the scientists of the Leipzig University who in 2001 together with Barg I. M. and Manyuk V. V. visited the Quarry. The first article in which the survey data on sharks from the Paleogene deposits of Dnipropetrovsk were presented was published in 1985 by the German paleoichtyologist O. Iekel (Iekel, 1895). A. Muller and O. Rosenberg studied the oolites of Osteichthyes (over 40 forms) and substantiated the actual value of this group of fossil remains for solving the issues of Paleogene stratigraphy. According to the authors` conclusions, most oolites of the complex are known from the layers of the Bartonian and Latdorf, and some were determined for the first time at this stratigraphic level (*Ariidarum germanicus, Parascombrops martini, Sparidarum noetlingi*) (Rozenberg, 2001; Müller, & Rozenberg, 2002, 2003).

The main material.

During our study in the territory of the Dnipropetrovsk Sheet (M – 36 – XXXVI) GDP-200 (further geological appraisal of the area in the scale of 1:200,000), there emerged a question of determining the stratigraphic position of the Mandrykivski Layers and their volume, determining their facies specifics and borders of the distribution, and most importantly, at last, 120 years after their discovery, giving them taxonomic range of "the layers with geographic name". When considering the application of V. V. Manyuk, the Cenozoic Commission of the National Stratigraphic Committee of Ukraine took into account that the Mandrykivski Layers are a shallow-water equivalent of the Obukhiv Suite, the distribution of which is limited by the Paleo-depressions of the north-east slope of the Ukrainian Shield. The deposits of the Mandrykivska fauna are distributed within the Vilnohirska, Borodaivska, Samotkanska, and Shatohynska, Troiitska and Myroliubivska Paleo-depressions. They are embedded with signs of erosions on coal-terrigenous formations of the Buchatska series or directly on the Precambrian rocks. They are overlapped by deposits of the Mezhyhirska suite or younger formations. The decision was made to approve "the Mandrykivski Layers" as a separate stratigraphic unit "layers with geographic name". As stratotype of the Mandrykivski Layers, the south-east slope of the Rybalsky Quarry was proposed, within which the layers outcropped at the distance of around 200 m, having the thickness of to 3.2 m and the exploitation of the granites in this direction at the time was not planned (Manyuk, 2003b).

The structure of the fifth or the Zavadivsko-Dniprovska above-floodplain terrace of the Dnipro, for the first time exposed by one of the ridges of the Quarry in 2002, is considered in detail. The structure of the Quaternary deposits in the Rybalsky Quarry, despite not being designated as having European significance, is extremely valuable for Ukraine. For the first time, the author drew attention to the specific section of the Quaternary Layer of the Quarry during the INQUA Conference in Ukraine in 2001 (Manyuk, 2001). In order to describe section 5 of the terrace, the history of the issue needs to be reviewed. In the abovementioned article by Shyrokova O. Z. et al (Schyrokov et al., 1986), the authors made an unexpected conclusion about the origin of the Mandrykivski layers, identifying them to fluvio-glacial deposits. Secondly, re-deposition of the fauna was indicated by Petrenko A. A. (Petrenko, 2003) based on questionable evidences which were disproved by the following researches (Barg, Manyuk, 2004). It is worth quoting the conclusion of O. V. Amitrova, who writes "The persuasive argument against the views of Shyrokov and Dyssa is that in location the fauna is well preserved, including fauna extremely rare for the Middle and the Upper Eocene of Ukraine, and therefore there is a possibility that while retreating the glacier collected the material from several (at least two) unique locations of the fauna of different age and drove them dozens of kilometers, mixing and depositing them, not harming the integrity" (Amitrov, 1986). Bringing up this discussion is not an accident. The southern border of the thickest Dniprovsky (Riss) glaciations remained depicted on the maps unchanged for over 130 years, since S. M. Nikitin recognized it in the valley of the Dnipro at 48°42´ N, i.e. current Domotkan village. Therefore, during geological surveys in the territory further south from this latitude, the discovered deposits which looked like fluvioglacial were identified to river alluvium. Thus, the exposure of section 5 of the terrace with clear signs of fluvio-glacial currents in the lower part of the Dniprovsky loess in the area became a notable sensation (Manyuk, 2002a). At the same time, this was so unexpected that it remained unreported in the publications. Nonetheless, we shall return to this later.

An important constituent of geodiversity of the Quarry as a geologic monument is the ancient Precambrian basement, the peculiarities of which were for the first time described in 2002 (Manyuk, 2002a). According to these data, the oldest formations in the Quarry are crystalline rocks of the Dnipropetrovsk infra-crystalline ultra-metamorphic complex of Mesoarchean (Azovian) with absolute age of 3.4-3.2 B years. It is a complex conjunction of grey and light grey gneissoid granite and migmatites of mostly tonalite and tonalite and trondhjemite composition, dark grey (to black) dense massive or gneiss-like amphibole-biotite crystalline schists of average composition and dark massive or low schistose amphibolites with numerous veins of aplite and pegmatoid microcline granites, with interveins of tremolites, actinolitite, biotites. In the ledges of the Quarry and along them, one can see a complex evolution of the composition due to numerous folded deformations and multi-phase pattern of development of various components of the complex. There are broadly distributed palingenetic and injection-metasomatic migmatites with broad diversity of texture types and numerous relic fragments of supracrystal substrate. The large area of artificial outcrop and absence of weathering of rocks in the lower ridges of the Quarry allow monitoring the changes in the structures and textures of the rocks, pattern of boundary zones of the layers, and the processes of biotitization, chloritization, silicification and epidotization, determining the present systems of fractures and determining elements of their embedding (Manyuk, 2002a).

After A. Muller and O. Rosenberg, starting from 2004 the research on the Rybalsky Quarry`s oolites of Osteichthyes has been continued by M. I. Udovichenko and A. V. Bratishko. A complex of oolites of 29 species of Osteichthyes was distinguished, eight of which were unknown until then for this location. M. I. Udovichenko came to the conclusion that the glauconite sands of the railway bridge, studied by V. Domger, are older than the detritus clayey sands of the Rybalsky Quarry, and most likely correspond to the lower part of the Priabonian stage (Udovychenko, 2009, 2010; Bratishko, 2009) .

The studies of the German scientist Dirk Fehse in 2011 in the Mandrykivski Layers revealed a new species from the Cypraeoidea family – *Eotrivia procera* sp. Nov. In his work, Dirk Fehsa wrote: "In the following this species, new to science, is described as *Eotrivia procera* sp. Nov." (Fehse, 2011).

Peculiarities of the geological section of the Quaternary deposits in the Rybalsky Quarry are most accurately described in the article "Quaternary deposits in the Rybalsky Quarry of Dnipropetrovsk" published in 2014 (Manyuk, 2014).

Results and analysis.

Long monitoring of the peculiarities of geological structure of subaerial and subaqueous deposits of the Anthropogene Epoch in the ledges of the Quarry clearly demonstrates the great value, completeness, and at the same time, certain exceptionality of separate elements of the Quaternary section. The Middle-Upper Pleistocene part of the section significantly exceeds the one exposed in the Sazhavtsi ravine, where the stratotype of the Kaidak fossil soil the section composed of Quaternary deposits is located (Manyuk, 2014). If in Stari Kodaky one can see only fragments of the section exposed by the lateral deep gullies and in the condition of overburden removal, one ledge of the Rybalsky Quarry represents a complete section of alternation of fossil soils and loess horizons – starting from present day chornozem to the Vytachivsky fossil soil, and another ridge located lower has a notable outcrop of a large fragment of the section ranging from Udaisky climatolite to the Zavadivsko-Dniprovska terrace, and in the north-west part of the Quarry, there is the remaining part of the section from the Tilihulsky horizon of the lower Pleistocene to the Kryzhanivsky Upper Eopleistocene inclusive. Without any exaggeration, we should state that the Rybalsky Quarry is the only place in Ukraine, where one can see an exceptionally full section of 19 horizons of the Quaternary system (the Kryzhanivsky climatolite to the present day soil) without any need of overburden removal. Even if the Quarry would have been worked-out, and not operating, the section of sedimentary rocks is destined to be ruined under the action of natural geological processes, unlike the crystalline Precambrian rocks. This obliges us to give primary characteristic of the accessible section, hoping to attract attention to it, involve the interested community in its thorough study using analytical researches as an important key section of the Quaternary system.

1. eH – Current soil. Soil-vegetative layer is represented by low-humus micelle-carbonate chernozem with poorly developed illuvial horizon (0.3 – 0.8 m). In most sections the soil has no structure, loose, almost always with the signs of technogenic mixing. Similarly to the area below, the embedded loams are different by coarser dispersive composition (to loamy sand) due to vicinity to the Dnipro.

2. vdPIIIpč – the Prychornomorsky horizon. The loam is brown-pale yellow, light, loess-like, microporous, limey, loose, with small amount of carbonate micelle, large aleurite structure (to loamy sand), with singular molehills, indistinct vertical prismatic structure. The boundary surface with the lower embedded soil is plain, distinct. The roof has signs of processing by the Holocene soil development. Thickness is up to 0.9 m.

3. ePIIIdf – the Dofinivsky fossil soil. Loam is light greyish brown, light, macroporous, loose (to aleurite), calcareous, in the lower, illuvial, part is exposed to light, with thin coatings of carbonates and micelle, rarely hydroxides of manganese, with signs

Fig. 1. The upper part of the section of the Quaternary deposits (Holocene, Prychornomorsky and Dofinivsky climatolites).

of gleyization. The lower boundary is uneven, with inflow pattern. Thickness equals 2.10 m.

4. vdPIIIbz – the Buzky horizon. The clayey sand is light yellow-pale yellow loess, light, homogenous, significantly calcareous, macroporous, friable, large-aleurite, of prismatic structure with carbonate micelles. The lower boundary is distinct, even. Thickness is 1.6 – 3.0 m. As we know, loess of the Buzky horizon in Ukraine in many sections contains interlayers and inclusions of volcanic ash, which is being attributed to the eruption of the Italian super volcano Phlegraean Fields 39 thousand years ago (Kosmachev,V.G., Kosmacheva, 2018). From this perspective, the Buzky loess, notably outcropped in the Quarry, definitely requires further study (Fig. 2).

ticeable amount of fine-grained sand), homogenous, with wedge-shaped structure, significantly calcareous with carbonate pseudo micelles, with singular cryoturbate, with small carbonate concretions (up to 0.5 cm), with point-like inclusions of manganese oxides. Thickness is 3.0 – 3.5 m.

7. ePIIIpl$_2$ – the Prylutsky fossil soil is represented by the suite composed of two soils. The upper soil is a grey to dark grey loam with brownish tone, averagely or just slightly consolidated, calcareous, fine-aleuritic, with prismatic structure, with indistinct lower boundary. The upper boundary is indistinct and uneven. The rock becomes lighter downward, obtaining brownish tone, gradually transferring to the lower layer. Thickness is 1.2 m.

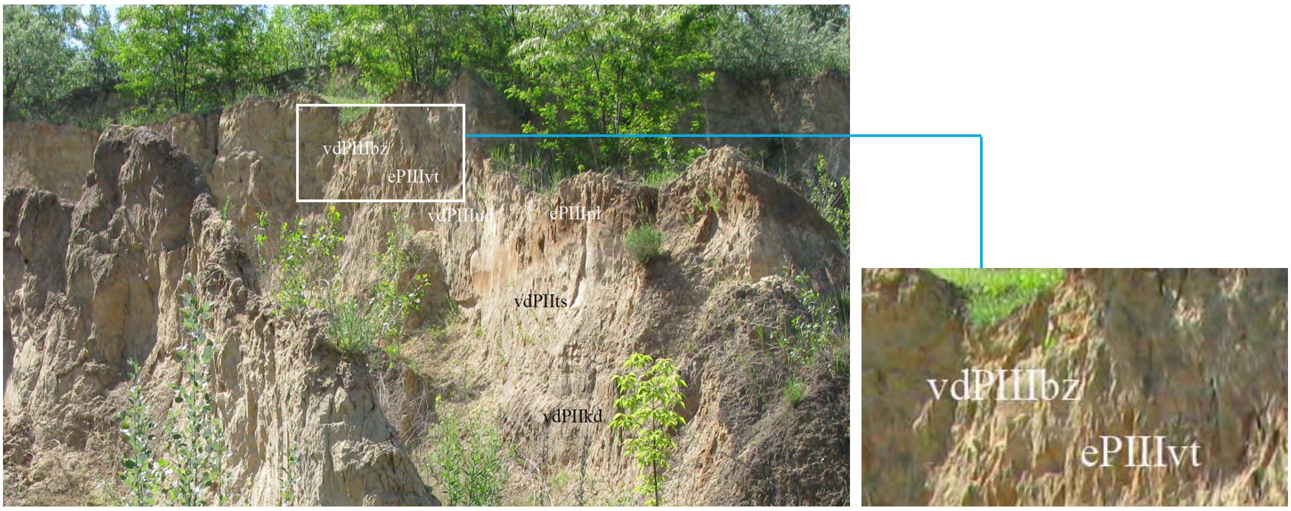

Fig. 2. The Buzky horizon in the southern part of the Rybalsky Quarry with increased fragment

5. ePIIIvt – the Vitachevsky fossil soil. The loam is brown with reddish tone, light, limey, fine-aleurite, prismatic structure, in the lower part with indistinct lightened illuvial horizon with carbonate efflorescences, small point-like carbonate inclusions (0.2 m). In the upper part of the layer, the soil is distinct by greater density and signs of ferruginization. The lower boundary is uneven, with inflow pattern. Thickness equals 1.3 – 1.8 m (Fig.2).

6. vdPIIIud – the Udaisky horizon. The loam is pale yellow-yellow, light, loess-like, macroporous, loose, composed of large-aleurite (to aleurite with no-

8. ePIIIpl$_1$ The Prylutsky fossil soil. The lower subhorizon of the suite of soils. The loam is grey-brownish-brown, calcareous, macroporous, of prismatic structure, homogenous, in some places in the lower part (0.3 m) transitions into carbonate white illuvium. The upper and especially the lower boundaries are uneven, indistinct. Thickness is 0.7 m.

9. vd P III ts The Tiasminsky horizon. The loam is yellow and pale yellow to light pale yellow, light, loess-like, fine alleuritic, light, macroporous, of prismatic structure, highly calcareous, with small amount of carbonate pseudomicelle, and is homogenous in the

Fig. 3 The Udaisky and Prylutsky horizons in the sections of the Rybalsky Quarry

upper part. Thickness of the massive loam is up to 1.5 m. Lower, the loam is different by presence of several interlayers of grey interstadial soil of 10-15 cm. Its texture has coarse layers, with alternation of pale yellow-yellow loess-like loam of large aleurite structure (to fine-grained sand) of darker brownish-brown colour, closer to light one according to the structure. The loam is loose, friable. Thickness is 1 m. In the northern-western part of the Quarry, in the lower part of the Tiasmynsky loess, in the regions of the vertical structure, there are well-developed dense carbonate formations of elongated form of 1-3 cm diameter. The rock in this section is looser, of shell-shaped structure. The upper boundary is uneven, gradual, with notable signs of influence of pedogenesis of the Prylutsky period, the lower boundary is distinct, even.

10. $ePIIkd_2$ The Kaidatsky fossil soil. The upper soil of the suite of the soil. It is loam of dark grey colour, chernozem-like (close to podzolized chernozem), swollen and insignificantly consolidated, large-alleuritic, of prismatic structure, limey, homogenous, without any carbonate inclusions, with singular molehills filled with darker soil, with insignificant amount of dendrites of manganese oxides, with distinct and even upper boundary and gradual, tortuous lower one. Thickness is 1.1 m (Fig. 4).

11. $ePIIkd_2$ The lower soil of the suite of the Kaidatski soils. The loam is dark grey brown, grey with brownish-brown tone, calcareous, macroporous, of prismatic structure, large-alleuritic, the lower part of the layer has well noticeable illuvial horizon with lightened area, more carbonate, with small point-like

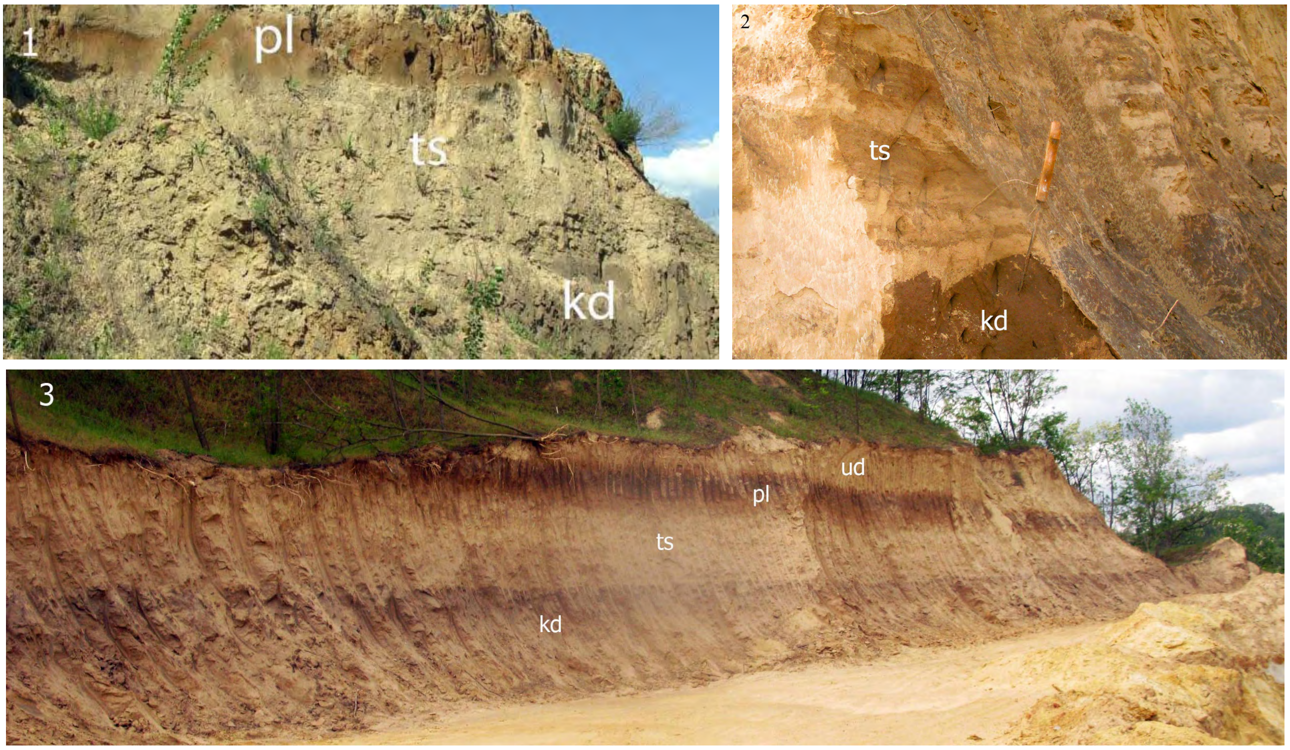

Fig. 4. The Tiasmynsky climatolite in the section of Quaternary deposits in the north (1) and south (2nd fragment with interstade, 3 – overall view) parts of the Quarry

inclusions of carbonates and their pseudomicelles, less homogenous, denser. The lower boundary is distinct, uneven, with inflow pattern in some places. Thickness varies 1 to1.6 m. (Fig. 4).

Somewhat different is the profile of the Kaidatsky soil in north part of the Quarry, where it is lighter (grey), homogenous, consolidated and overlapped by contemporary soil (Fig. 5). The third type of the profile is exposed in small gully in the central part of the Quarry, and is dark grey chernozem-like loam, calcareous, homogenous, large-alleuritic (Fig. 4, 1). This section of this gully has in particular for over 20 years served as an excellent etalon section of the Middle-Upper Pleistocene subaerial deposits for practical education of Geology students and for scientific surveys. Unfortunately, it is now overgrown with trees, while the slopes need digging and clearing (Fig. 2).

12. vdPIIdn$_3$ The Upper Dniprovsky stade. The loam is light-pale yellow-yellow, light, loess-like, highly calcareous, homogenous, in the upper part of the layer is dense, calcareous down to the lower part, fine-alleuritic, of wedge-shaped structure, with singular small swollen carbonate concretions (2-5 mm) and thin coatings of manganese oxides. Thickness of the layer is 3.5 m. It should be noted that the shucks-shaped mentioned above (the Dniprovsky, Tiasmynsky and others) are obviously typical loesses, and the name “loess-like loam” is retained exclusively based on its traditional use during the performance of geological surveys.

13. l,vdPIIdn$_2$ The aeolian-deluvial and lake deposits of the Middle-Dniprovsky stade. The loam is thin-layered, significantly calcareous, non-homogenous. It is a thin layer of greyish-yellow (to pale aleurite with light brownish tone, of coarse granulometric

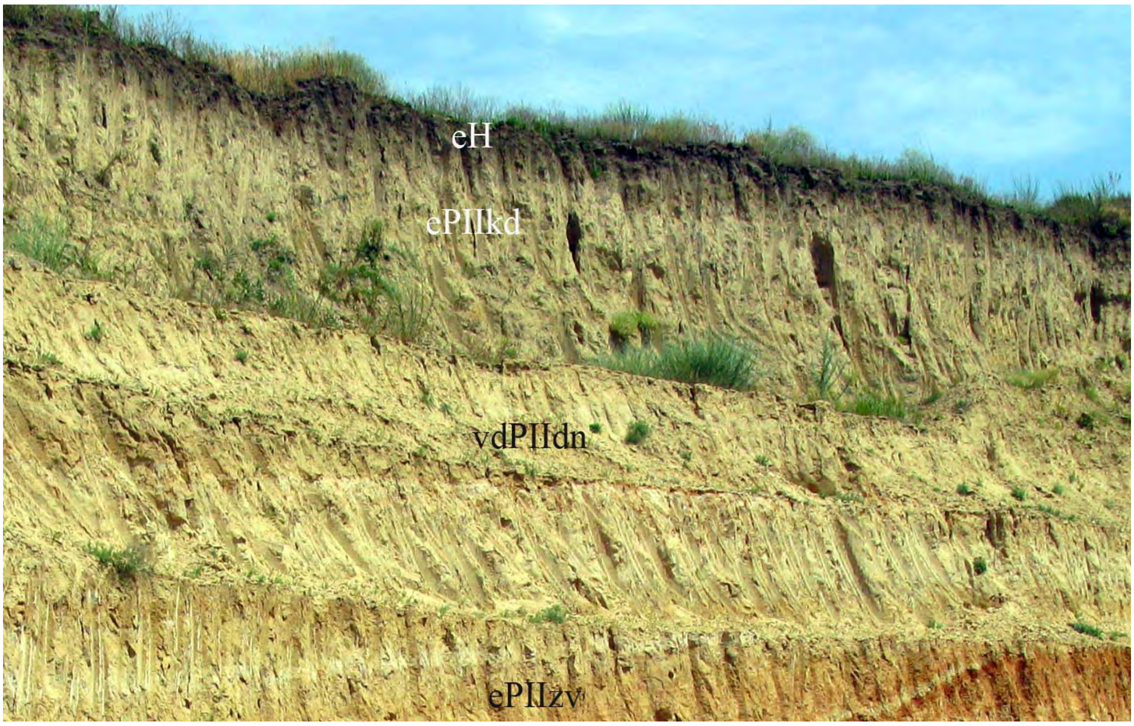

Fig. 5. Section of the Middle Pleistocene deposits in the north part of the Quarry (the Kodatsky and Zavadivsky fossil soils and the Dniprovsky loess)

Fig. 6. The upper and lower boundary of the Kodatsky soil with loess horizons

Fig. 7 Linear erosive processes in loess of the Dniprovsky horizon

content (to fine-grained quartzintic sand). Thickness of interlayers is irregular, varying several millimeters to 1 cm, with uneven, often having wavy surfaces of overlapping. Thickness is 1.8 m. Swollen, very soft, silty soil, very porous, easily erodible by even least water currents and on the surface of the Quarry`s ridge is composed of the lake Dniprovsky loam, there are formed quite deep tortuous erosive washouts. It is another attraction of the Rybalsky Quarry, important for practical education of students (Fig. 7, 8).

14. fg,l PIIdn$_2$ Fluvioglacial deposits of the lower stade of the Dniprovsky climatolite. Sand is quartziferous, ochre-yellow, non-homogenous, bright green and red, with signs of intense ferruginization in some places, overlaps with light yellow, poorly sorted, mostly fine-average grained, with interlayers of grey-

Fig. 8. Lake deposits of the Dniprovsky Age in the north-east part of the Quarry

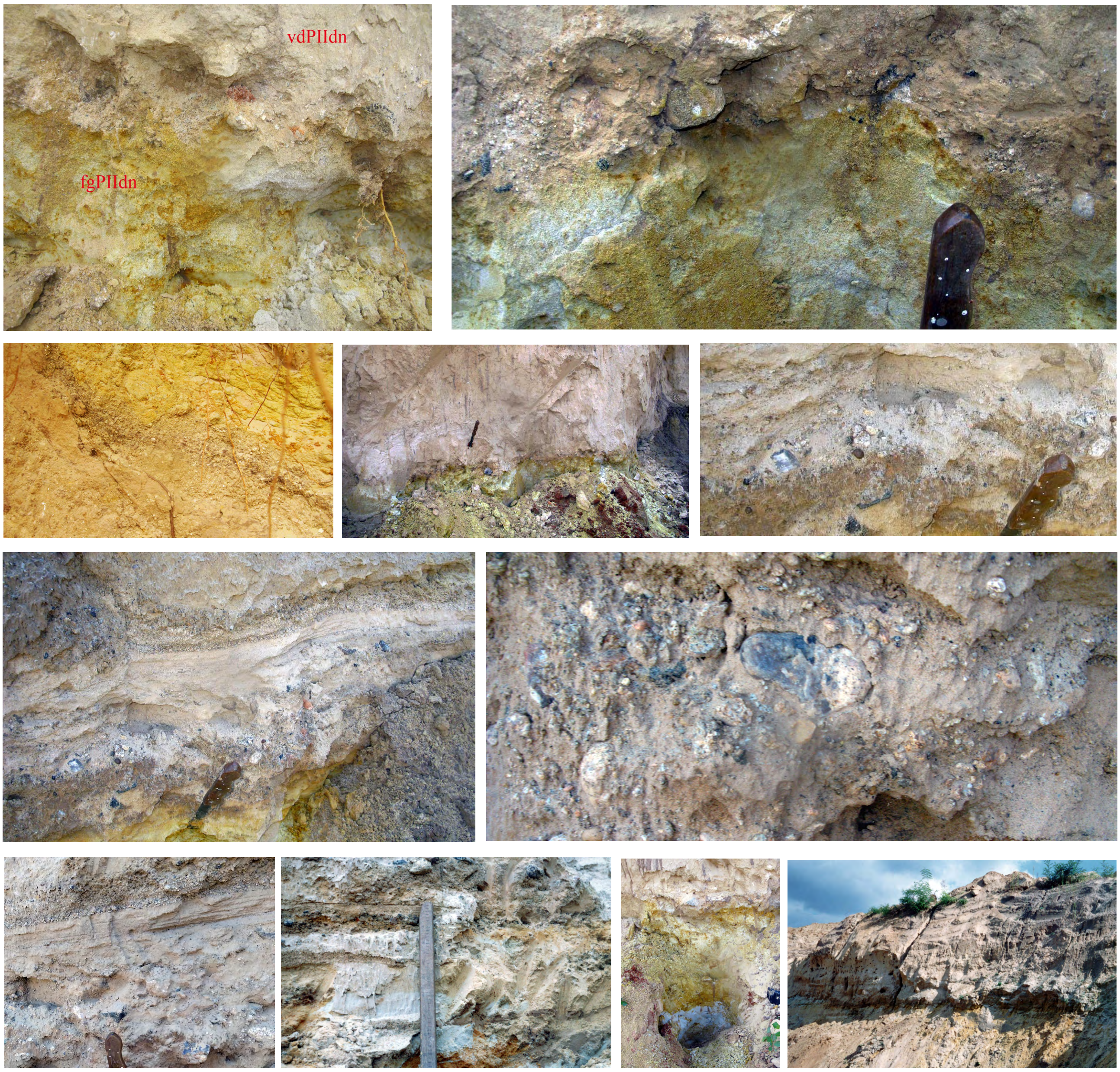

Fig. 9. Fragments of the section of the boundary zone of aeolian-deluvial and lake-glacial loams with fluvioglacial deposits.

yellow aleurite. In the upper part of the layer, the interlayers of fragmented non-sorted material from coarse sand and gravel to large-grained sand and even boulders, the size of which varies 10 to 20 cm, rarely to 0.4 -0.6 m. Fragments, both rounded and angular, are different in shape and composition. These are granites of different composition and different colour, gneiss, migmatites, amphibolites, diabases, pegmatites, quartzites and vein quartz, often with epidote, sandstones of different colour, sometimes quartz-like, corrosive, with signs of alkalinization and ferruginization, gabbro, cataclise, diorites, etc. Thickness of separate layers is 3-5 to 20 cm. Sands embedded lower also contain a small amount of debris. The total thickness of the layer is 0.7 to 1.2 m. For the first time such a section was exposed in the Rybalsky Quarry back in 2000, but the presence of typical fluvioglacial deposits on the latitude of Dnipropetrovsk was so unexpected that they were identified by the author of this article to large river alluvium (Manyk, 2001a). We mapped similar deposits much farther south, in Kobeliaky district (the Dnipro-Donets Rift), in a typical area of distribution of the Dniprovsky (Riss) glaciation. At the same time, previous articles contain no mentions of signs of fluvioglacial deposits south of the Borodaiivski eratic boulders. Now, there are more than enough evidences of presence of an outwash plain, and they are more than convincing (Fig. 9).

A question occurs whether the origin and interlayer of red-brownish (to red) clay is located lower in the section, under the layer of fluvioglacial gravel-crushed stone deposits. Directly underneath it, the section of the fifth (Zavadivsko-Dniprovska) terrace begins, having emerged at the beginning of the Zavadivsky period, which was before the Dniprovsky (Riss) glaciations. At the final stage of development of the alluvium of the terrace, the current in the river valley significantly slowed, creating conditions for accumulation of clayey material in the floodplain of the Dnipro, especially in the depressions and their periphery areas. As we know, the Zavadivsky fossil fauna is the first beneath the surface, which has distinct red colour, therefore it is no surprisethat it was driven away from the drainage divide which at the time was the arena of its accumulation. The deposits have no obvious signs of re-deposition and development in the complex dynamic conditions of the river valley.

The clay is bright red, dispersed coarse (to loam), limey, with particles of carbonate concretions and inclusions of non-sorted and non-rounded debris material (diorhytes, granites, quartz, sandstone) with dendrites of manganese oxides (Fig. 10).

desquamation have created unusual, to some extent exotic morphological forms of Precambrian rocks. Therefore, the next attraction of the Quarry may be considered the giant boulders, "dressed in a shirt" of clayey weathering crust and surrounded by shells of weathered granites of various forms (Fig. 11). It has to be noted that on these exotic boulders, outside the range of distribution of the Mandrykivski layers, there are embedded brownish-green clays which overlap these layers and the lake genesis of which could not be considered undeniable. Nonetheless, we shall get back to them later.

16. a^5 PII zv-dn the Zavadivsko-Dniprovska (the fifth or the Hadzhybeiska) above-floodplain terrace. Sand is quartziferous, of yellowish-grey colour, with interlayers of grey, ochre-yellow and white, well sorted, fine- to average-grained, calcareous, in the lower part of the layer it is slightly clayey, more consolidated, of thin- and average lamination, with wavy-parallel texture in some places. The layer of sands of 12 m

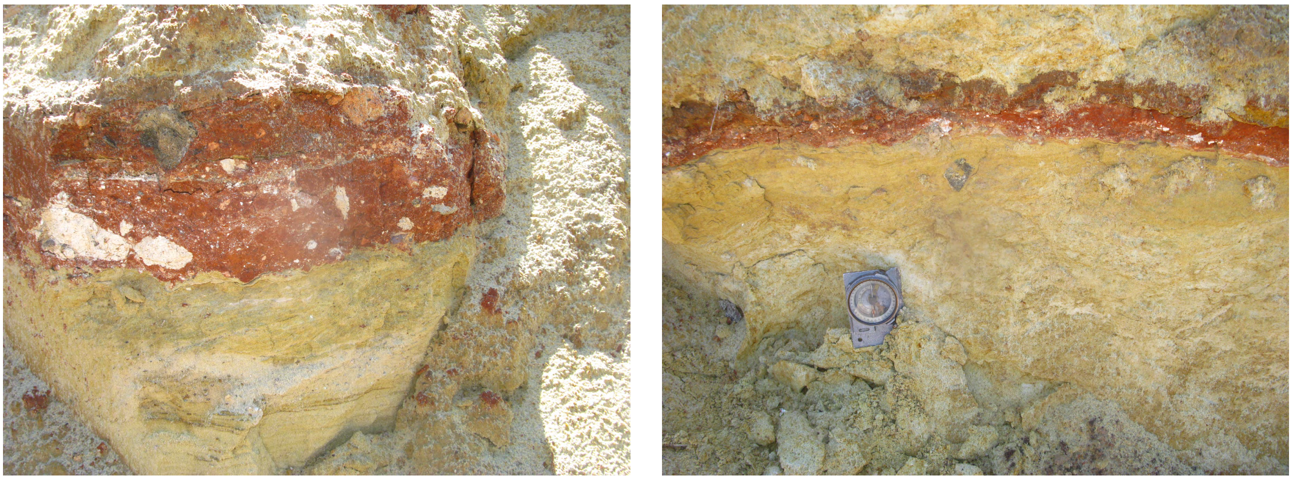

Fig. 10. Fragment of the layer of fluvioglacial deposits with interlayer of red-brownish clay and with low amount of non-rounded and non-sorted debris.

15. fg, l PIIdn$_1$ Fluvioglacial and lake deposits of the Lower Dnipro stade. Sand is quartzitic, yellow-grey, fine-grained, calcareous, poorly sorted, non-homogenous, slightly clayey in some places, with distinct horizontal, slightly wavy lamination, with a high amount of small debris material of the same composition and compound as clay (Fig. 10). The upper boundary is distinct and even, and in the foot the sand layer gradually transforms into alluvium of the terrace which was washed out during the Early Dnipro period.

At higher hypsometric level, this sand is embedded directly on crystalline basement, the rocks of which in this area of the Quarry underwent intensive weathering. The totality of quite specific physical-chemical processes of weathering, intensive

thickness is distinctively divided into two parts. In the upper one, lighter more loose sands and friable sands with notable layering dominate, while in the lower one – darker (ochre-yellow) ones with only slightly noticeable lamination. The layer of sands exposed by the Quarry is bent in the central part of the section, and the layers are embedded toward the center at an angle of 7° in the north (from the side of the Dnipro River) to15° in the south (Fig.12).

The presence of a thick alluvial layer formed at the beginning of the Zavadivsky period and the relics of red-brown Zavadivsky fossil soil in the roof of the terrace well correlate with presumption of P. Gozhyk (2013) that this part of the section corresponds to the Lower Zavadivsky-Lyhvinsky interglacial period (Holstein) (Gozhik, 2013).

Fig. 11. Consequences of physical-chemical weathering of crystalline rocks of the Precambrian basement in the form of disintegration, ferruginization, hydration reaction, dialysis, hydrolysis and desquamation

In the upper part of the terrace, in its roof, the lateritic kirasa (ferricrete) formed most likely in the final stage of the development of the terrace alluvium, when the surface ceased to be flooded with water, and the siliceous-clayey-ferrugenous formations underwent oxidation and densification in the climatic conditions close to the tropical (Fig. 13).

Interestingly, we saw such formations in the upper part of the valley of the Psel River, in Shpylivka village during the study of geological relics of Ukraine (Bezvynniy, Bobrov, Bryanskiy, Vashhenko, Volnenko, Manyuk, ... Shevtsova, 2011). There, siliceous-ferrugenous consolidated crusts are also embedded on the boundary of fluvioglacial layer of the Dniprovsky glacial and the layer of horizontally layered sand deposits of the Psel river terrace, indicating similar conditions of lithogenesis and diagenesis within these territories (Fig. 14).

Fig. 12 Boundary of the layer of sands of the Hadzhybeiska terrace (the fifth) of the marine deposits of the Upper Eocene (Mandrykivski Layers)

Fig. 13. Siliceous-clayey-ferrugenous ferricretes (lateritic crust - kuirass) at the boundary of fluvioglacial deposits with the alluvium of the fifth terrace.

In most of the literature sources it is considered that such solid crusts or duricrust (ferricretes, silcretes, calcretes) are characteristic exclusively for regions with tropical climate and the condition for their development is presence of a source (particularly iron oxides), its transportation (in our case capillary elevation from the sands of the Hadzhybeiska terrace) and deposition with subsequent diagenetic changes (GanDixon, 2009). This is confirmed by the lenses of quartzitic, white, fine-grained, well sorted sand below the cuirass horizon (Fig. 13). Iron oxides have been completely drifted out of the sand, unlike the ferruginized laminated sands, among which it is embeded.

The age and origin of the clays which are embedded on the foot of the fifth terrace and on the surface of the Mandrykivski Layers or the crystalline Precambrian rocks remains a subject of discussion and require

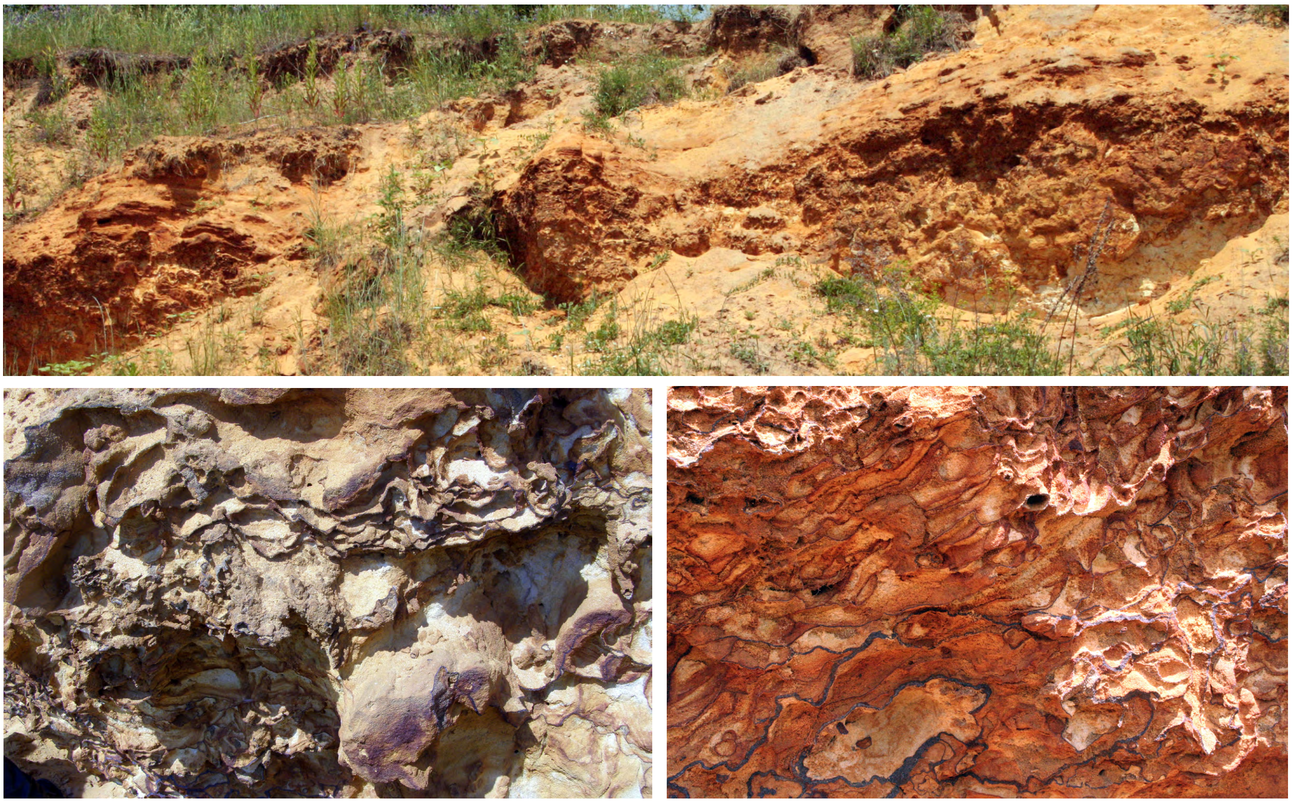

Fig. 14 Siliceous-ferrugenous rocks (ferricretes) in the upper part of the valley of the Psel river in Sumy Oblast

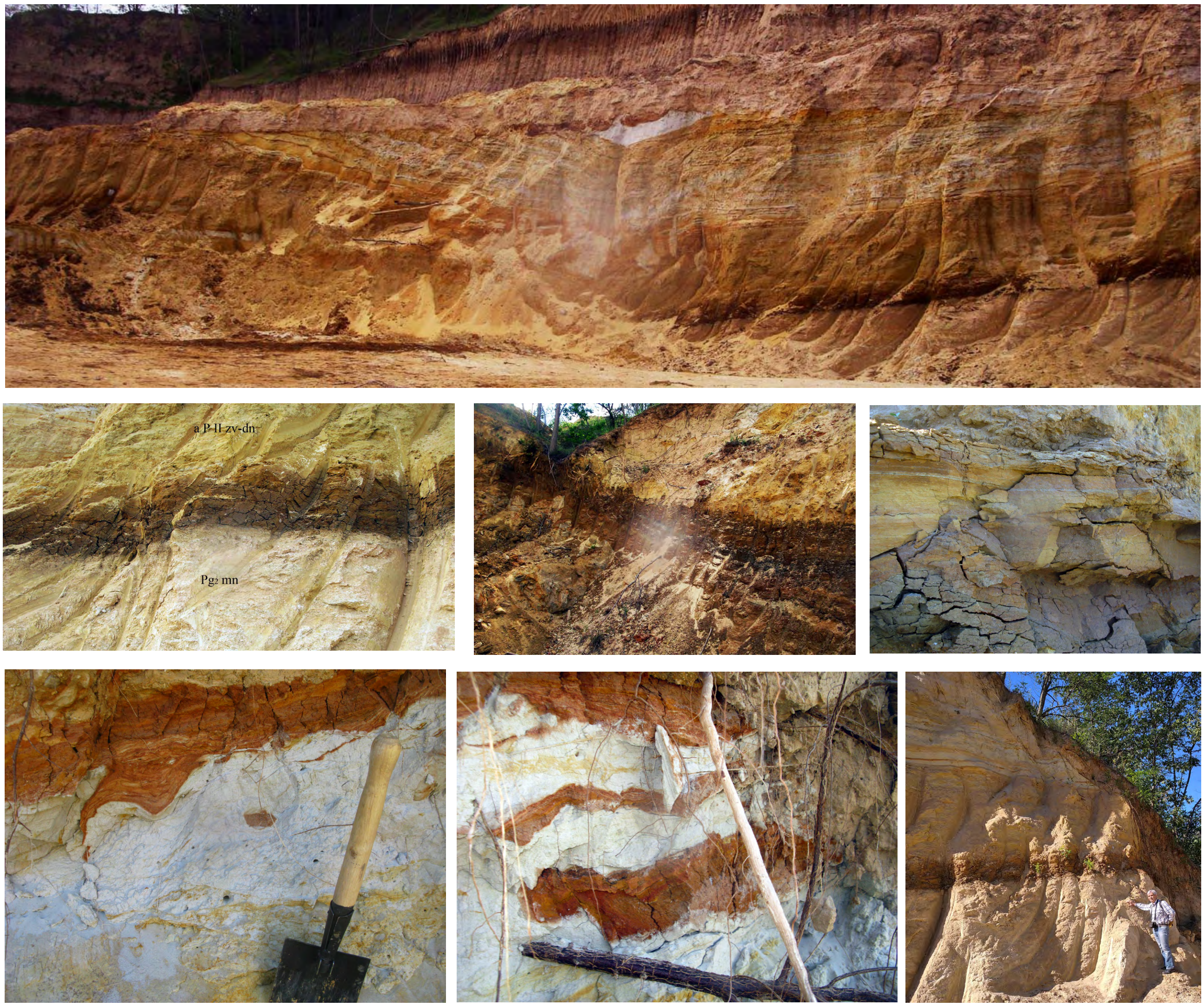

Fig. 15 Red-brown, ochre-brown and dark-green clays in the foot of the fifth terrace 200 m away to the north-east, in a higher ridge of the Quarry, and therefore on higher hypsometric level (+68 m, i.e. 10 m higher), there is an exposed fragment of geological section ranging from the Tilihulsky loess horizon to the Kryvozhanivsky fossil soil (top-down).

additional surveys. Clays are non-homogenous. In the places where they are overlapped by detritus-carbonate rocks of the Mandrykivski Layers of the Upper Eocene, there are reddish-brown, viscous, plastic clays, quite dense in dry state, with glossy surfaces of colloid coating, thin- average platy texture, with fine-shell hydromicas on the surfaces of the jointing, with wells and scattered fine-average grained sand, varying from thin- to large-banded, with small point-like carbonate inclusions and dendrites of manganese oxides. If we assume a marine origin of these clays, they are underwater weathering crust (terra rossa) formed in the processes of halmyrolysis or are the product of dissolution of carbonate silt enriched with detritus of mollusks, corals and other inhabitants of the warm Mandrykivske Sea. Further south, clays are embedded on rocks of the Precambrian basement and differ by their greener colour, with characteristic alternation of red-brown, blue and ochre clays, being more micaceous, often containing a large amount of sand-gravel material, deformed, because often contour and thus replicate the shape of large boulders of granites, the space between which they fill (Fig. 11). Clays often contain large boulders of granites, plagiogranites and conglomerates, both significantly weathered an solid, unaltered, up to 1.5 m in size. Thickness of clays ranges 0.7 m above the Mandrykivski Layers to 6 m on the rocks of the crystalline basement.

1. vdPItl Tilihulsky loess climatolite. Loam of grey-pale yellow, average, loess-like, consolidated, macroporous, of prismatic structure, loose, with carbonate micelles, with small amount point-like inclusions of manganese oxides, with singular molehills. Thickness is 1.8 m.

2. ePI lb Lubensky fossil soil. Loam is brownish-brown with reddish tone, slightly sandy, of prismatic structure, with singular small carbonate concretions, notably more abundant in the foot of the layer. Thickness is 1.0 m.

3. vdP I sl Sulsky loess horizon (cryoturbate).

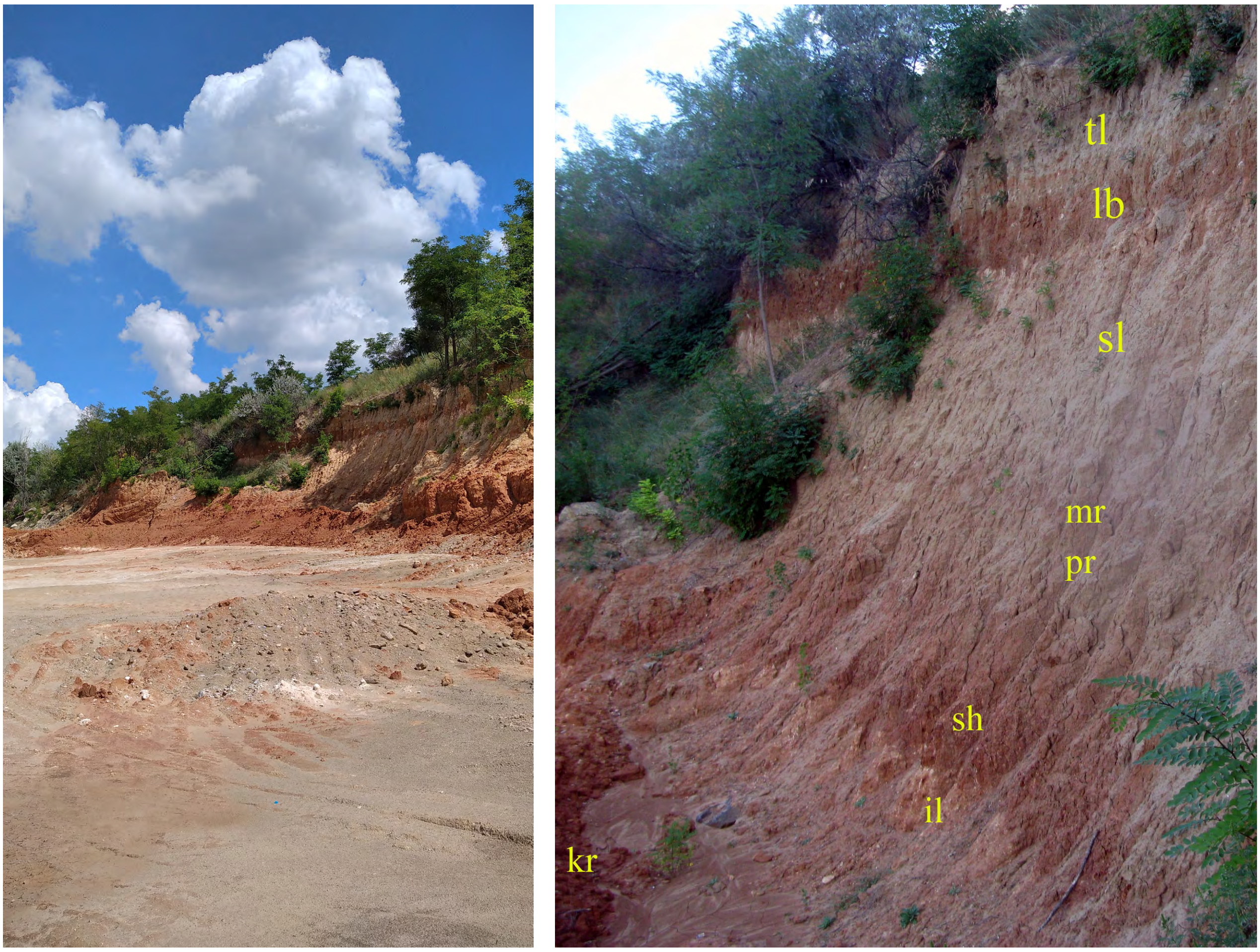

Fig. 16 Section of subaerial deposits of the lower Pleistocene link in the north-east part of the Quarry

Loam is grey-pale yellow to pale yellow-yellow, average, loess-like, with no sand, with many carbonate concretions of up to 15 cm. The upper boundary is uneven, with inflow patter. Thickness is 2 m. (Fig. 16).

4. ePI mr Martonovsky fossil soil. Loam is brown-red-brownish, heavy (heavy loam), dense, of prismatic structure, loose, large-aleuritic structure, with clearly seen illuvial horizon of varying thickness (0.1 to 0.5 m). The lower boundary is distinct, highly uneven with seepages. Thickness is 0.9 m.

5. vdPIpr Pryazov loess horizon. Loam is grey-pale yellow, heavy, with no sand, dense, with abundant particles of small carbonate concretions, with high number of thin layers of dendrites of manganese oxides on the surfaces, of prismatic structure, large-aleuritic. Thickness is 1.1 m.

6. ePIsh Shyrokynsky fossil soil. Loam is dark red-brown, darker in the middle part of the layer, highly carbonate, with heavy loam (close to coarse-dispersed clay), non-homogenous, in the lower part of the layer there is a large amount of carbonate material varying in size several millimeters to 15 cm. Clearly noticeable illuvial horizon which with inflows is unevenly embedded on clays of the Illichivsky climatolite, Thickness is 1.3 m.

7. l,vd EII il Illichivsky climatolite. Clay is brown-grey, non-homogenous, with signs of hydromorphism and soil formation, pile-boulder structure, with shimmering surfaces of colloid coating, with large amount of dense carbonate concretions. The upper boundary is indistinct, and very uneven, the lower one is more notable and distinct. Thickness is 0.5 -0.7 m.

8. e EII kr Clay is bright red-brown, largely-dispersed, consolidated, slightly sandy, with large amount of consolidated and loose carbonate concretions which often form vertical column-like forms with dendrites of manganese hydroxides. Thickness is 4 m. Lower down, large granites are embedded.

West of the described outcrop, there is a fragment of section, the structure of which is not similar to the plots located nearby. Despite the fact that the section looks natural, it is hard to explain it logically (Fig. 17). If it was a shift of the block with another structure, than how can one explain the signs of conjunction of different regions, which are not seen? In that case we would have to solve the problem of unnoticeable signs of conjunction of various regions. Perhaps, the causes were neotectonics, or glaciodislocation of frozen blocks in the Dniprovsky period. It has to be

Fig. 17. Fragment of the structure of Quaternary deposits with signs of disorder of initial embedding

noted that the relief there is notably different. The layers are inclined 18 °, while being embedded horizontally in the first described fragment. The question remains open to discussion.

Higher and north of the main section (in Fig. 4), there is a fragment of ridge which gives us a great opportunity to see the Upper Pleistocene part of subaerial deposits of the Quaternary system (Fig. 18).

1. vdPIII pč Prychornomorsky climatolite, Loam is yellow-pale yellow, light, loess-like, macroporous, calcareous, fine-aleuritic, of shell-shaped structure, humus in the roof, with uneven gradual boundary. Thickness is 1.1 m.

2. ePIII df Dofinivsky fossil soil. Loam is light brown, light, homogenous, highly calcareous, loose, fine-aleuritic, of prismatic structure, with small carbonate concretions in the lower part of the layer. The boundary are distinct, even Thickness is 1.2 m.

3. vdPIII bg Buzky loess climatolite. Loam is light-pale yellow, loess-like, loose, macroporous, homogenous, slightly consolidated, of prismatic structure, with a small number of thin coatings of manganese oxides. Thickness is 2.5 m.

4. ePIII vt Vytachivsky fossil soil. Loam is brownish-brown with reddish tone, light, of prismatic structure, in the lower part of the layer has a clearly seen illuvial horizon, lightened, with small carbonate concretions.

Lower down, there is the Udaisky loess, described above, see Fig. 3.

However, the most exotic and non-exposed secrets of the Rybalsky Quarry are the outcrops of the

Fig. 18 Section of subaerial deposits of the Upper link of the Pleistocene

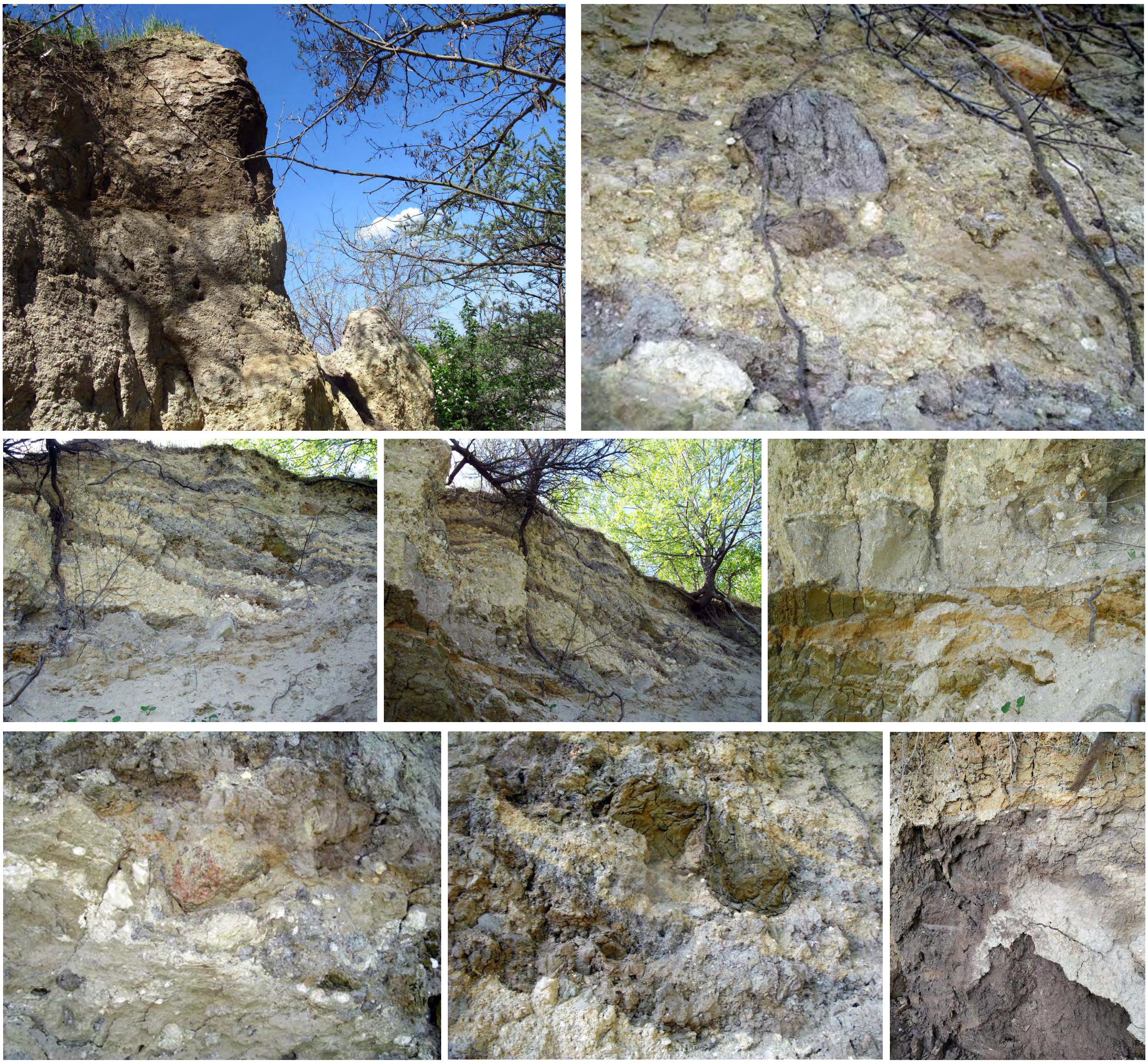

Fig. 19. Section of the "Mandrykivski" Layers or whim of lithogenesis and sedimentogenesis in the outcrop near the spring

Mandrykivski Layers in the north-west part of the Quarry near the well-known source, the lithological – facies composition of which has always encouraged researchers to provide it with status of re-deposited. Only in the study by Berezovsky A. A. and Demianova V. V. (Berezovsky, 2014), for the first time was this "mixtite" – it is hard to call it otherwise - described, being considered as a facies of the Mandrykivske Sea. These outcrops definitely need to be studied and discussed further, which is beyond the scope of this publication. However, the importance of the question and the necessity to solve it demands illustrative material of this section, which I leave with no comments.

Conclusions.

Many articles have focused on the geology of the Rybalsky Quarry, although it continues to surprise us with new discoveries. The main attraction of the Quarry is still the Mandrykivski Layers with unique fossil fauna of the Upper Eocene. However, in 2019, for the first time in over 50 years, a new fragment of the layers was exposed, which expands the possibilities of collection and study of the fossil remains of one of Europe`s best localities of the Priabonian stage deposits. Moreover, for the first time the upper boundary of the Mandrykivski Layers, which was earlier inaccessible, was exposed. Extremely informative is the section of subaerial and subaqueous deposits of the Quaternary system, represented in the Quarry by all links and 18 climatolites ranging from contemporary soil to the Kryzhanovsky horizon. In 2019, for the first time, in all the thickness, the 5 above-floodplain terrace (Hadzhybeiska) was exposed. Its roof was found to have clear signs of activity of fluvioglacial currents in the period of the Dniprovske glaciations. In the lower ridges of the Quarry, there is seen the complex evolution of composition of Precambrian crystalline basement due to numerous folded deformations and multiphase nature of development of various components of the complex. Palingenic and injected metasomatic migmatites are widely distributed with a great diversity of texture types and numerous relic fragments of supracrystalline substrate. Distinct signs of influence of the Dniprovske glaciation on the upper part of the Mandrykivski Layers were observed in the south part of the Quarry, where the structure of the section was deformed to such an extent that determining the genesis of deposits, lithological-facies peculiarities, paleogeography and the conditions of sedimentogenesis need additional special surveys. As earlier, the relevant question is still the protection of the territory of the Quarry with the outcrops of the Mandrykivski Layers and best fragments of the Quaternary deposits with the purpose of creation of geological relic (geosites) of nature of national significance (Bezvynniy et al, 2011).

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The protected area as a tourism eco-brand

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Abstract. Branding of the protected area plays an important role in the process of forming its attractiveness for the currently growing target market, focused on the consumption of environmental friendliness as an unconditional value. The results of literature review show that when the object of branding is a national nature park or any other nature protected object, intangible elements of the brand (affirmative opinions, beliefs and associations) must be based on the principle of eco-friendliness, and the tangible elements (logo, colours, design, semantic and visual effects) reflect this primary value. This is the so-called eco-brand which provides the ecological prerogative of the positioning object. The aim of this paper is to analyze the tangible and intangible components of Ukrainian national nature parks brands, their current market positioning, as well as the development of proposals for eco-brand formation of the national parks. The study tested text and visual content of Internet sites of Ukrainian national natural parks and analyzed their logos. As a result, most logos can be considered environmentally friendly due to their symbology and colours, but Internet sites are not customer and business oriented, and don't reflect the national parks positioning. Based on a sample of 87 on□ site visitor survey responses, two factors, the brand awareness and national parks attendance, were estimated. The brand awareness of Ukrainian national parks is critically small and directly depends on the brand awareness. The hiding place survey suggested that consumers do not identify national parks by logos and do not differentiate them well. The results of the survey of potential visitors were supported by the results of interviews with 8 ecotourism experts. Experts identified the current positioning for each national park, proposed changes in positioning based on the characteristics of the landscapes and hydrology, flora and fauna. Based on the findings of this study, the authors proposed a set of measures for the brand positioning of national parks within the framework of the eco-brand concept. The authors insist that the development of a national nature park in the concept of an eco-brand also means the introduction of environmental standards of landscape design, appropriate behaviour patterns and management approaches.

Keywords: brand, positioning, national nature park, tourism destination, ecotourism

Природоохоронна територія як туристичний екобренд

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Анотація. Брендинг природоохоронної території як туристичної дестинації відіграє важливу роль у процесі формування його атрактивності для зростаючого нині цільового ринку, орієнтованого на споживання екологічності як безумовної цінності. Встановлено, що у випадку, коли об'єктом брендингу є національний природний парк або будь-який інший природоохоронний об'єкт, нематеріальні елементи бренду (стверджувальні думки, переконання та асоціації) обов'язково мають гуртуватись на принципі eco-friendliness, а матеріальні (логотип, кольори, дизайн, семантичні та візуальні ефекти) – відбивати цю первинну цінність. Визначено, що в науковій літературі такий підхід називається еко-брендингом. Завданнями цієї статті став аналіз матеріальних і нематеріальних складових брендів національних природних парків України, їх поточне ринкове позиціонування, а також розроблення пропозицій щодо формування еко-брендів окремих національних природних парків. Проаналізовано контент інтернет сайтів національних природних парків України, їх логотипи та поточне позиціонування. Встановлено, що позиціонування більшості з них є неефективним внаслідок слабкої самоідентифікації та відсутності клієнто-та бізнес- орієнтації основних драйверів брендів. Виявлено, що екологічність бренду як така може і не призвести до бажаного ефекту – зростання атрактивності об'єкта, якщо сам бренд не відбиває його автентичність, не викликає у потенційного відвідувача сталі асоціації, бажання отримати унікальний досвід, не допомагає ідентифікувати та диференціювати. Оцінено поінформованість цільових аудиторій щодо діяльності та специфіки НПП України та рівень впізнання брендів. Виділено групи НПП за критеріями «відвідуваність-інформованість», охарактеризовано закономірний зв'язок між цими критеріями. Методом експертної оцінки визначено рекомендації щодо екологічного позиціонування брендів національних природних парків України. Запропоновано заходи щодо валоризації та просування еко-брендів природоохоронних територій. Встановлено, що розвиток національного природного парку в концепції еко-бренду у тому числі означає запровадження екологічних стандартів ландшафтно-просторового дизайну, відповідних моделей поведінки та підходів управління.

Ключові слова: бренд, позиціонування, національний природний парк, туристична дестинація, екотуризм

Introduction.

The question of the development of tourist flow concentration zones has been reflected in numerous publications by representatives of British, Australian, New Zealand, European and American scientific schools, in particular, N. Leiper, P. Pierce, W. D. Dwyer, and H. Kim, D. Bukhalis. They introduced into the scientific literature and developed the concept «tourism destination» as a business unit. They see this term as territorial objects of different levels, scale, and specialization which have become or may become centers of concentration of tourist flows due to certain factors and the presence of specialized infrastructure. The first studies in which national parks and other nature conservation sites were considered as tourist destinations appeared back in the mid 1970s (E. Moyo, 1975). In the mid-1990s, due to the actualization of ecotourism research, national parks were perceived in the scientific literature as a special kind of the tourism destination (D.L. Andersen, 1994).

The view of the destination as a business unit that exists under the laws of business (Ritchie, JR Brent, Crouch, GI, 2003) forms the basis for sustainable development of the territory, as it allows one to ensure a certain balance of economic and environmental interests of all participants in the tourism process within the destination: enterprises in the field of tourism and related industries; state or local authorities; local communities; public organizations; tourists. Besides, it allows one to apply to destinations traditional business tools, including marketing ones.

Tourism destination marketing traditionally focuses on forming and maintaining the appropriate image of the latter to ensure the growth of tourist visits (Marija Jankovic, Anđela Jakšić Stojanović, 2019). When the object of marketing is a protected area – an ecotourism destination – the marketing balances between the tasks of attracting visitors and encouraging them to a certain pattern of behaviour that is optimal for the preservation of ecosystems (Lisa M. King, Stephen F. McCool, Peter Fredman, Elizabeth A. Halpenny, 2012). Marketing management of protected areas, based on the principles of sustainability, can significantly improve the preservation, protection, promotion, and valorization of both natural and cultural heritage and it is a necessary prerequisite for their successful positioning in the global tourism market (Kvach, Koval, Hrymaliuk, 2018.).

Branding is the best tool for this task. Back in the early 1990s , specialists began to discuss the admissibility of the spread of branding technology in areas (Kotler, P., Gertner D., 2002). Further research has shown the scientific and practical feasibility of analyzing a tourist destination within the paradigm «destination – brand» if the brand is understood as a unique and competitive image of the territory for domestic and international positioning as an attractive place to visit (Davidenko, N. 2009). In fact, the territory of any configuration gets the opportunity to become a brand only when a potential visitor begins to identify it as some unique integrity, a theoretically possible place to travel. Thus, in the late twentieth century, it became clear that a destination with its resources, infrastructure, activities can be branded, although not as a regular product, but rather as a corporation (Ritchie, JR Brent, Crouch, GI, 2003) and, accordingly, can have its own brand capital with all its attributes.

Using branding strategies aimed at recognizing a specific protected area, its identification, and differentiation, it can attract the emotions of visitors and encourage positive behaviour, as well as improve the management of protected areas and ensure their sustainable development (Marija Jankovic, Anđela Jakšić Stojanović, 2019; Popova et al., 2020). Representation of a destination in the minds of visitors in modern research is seen as the main reason for choosing one particular object of visit over another, and therefore it can be used in competition at the regional level (L Dwyer, 2018). Highlighting the need to form several related associations to form a brand identity, Kotler & Keller (2008) emphasize the complex structure of the brand, which is formed not only of tangible but also intangible and visual elements. The intangible effects used for the presentation (Kotler & Keller, 2008) include the experience of visitors, their affirmative thoughts, beliefs, and associations (Echtner & Ritchie, 2003; Trung & Khalifa, 2019). This creates an emotional connection with a certain place, the desire to visit it, tell about it, and so on. Branding plays a key role not only in the promotion but also in the preservation and valorization of a certain area (Marija Jankovic, Anđela Jakšić Stojanović, 2019) because the presence of strong beliefs about the need to protect the territory, careful treatment of ecosystem components also have a positive effect on visitors' behaviour during their stay within the protected area. Lisa M. King, Stephen F. McCool, Peter Fredman, Elizabeth A. Halpenny identify three main strategies for branding protected areas: brand awareness, visitor education, and brand building (2012). Building brand equity means creating stable emotional experiences, and educating visitors – encouraging positive behaviour models before, during, and after visiting the destination.

In the late 20th century, Aaker (1996) and Kotler (2000) introduced the definition of «green brand» as a set of attributes and benefits associated with the reduced impact of the brand on the environment and its perception as environmentally friendly and in 2009 R.J. Orsato scientifically substantiated the concept of eco-brand, which was based on the differentiation of brands based on ecological prerogatives (R.J. Orsato, 2009). This became possible due to changes in the cultural paradigm of society, and thus in consumer behaviour patterns in which environmental motivation is increasingly prevalent. Tourism has certainly been affected by this trend. Research shows that social and psychological desire to escape from habitual life and the search for natural sites – natural monuments, interesting landscapes, the ability to observe or simply immerse oneself in wildlife, etc., become increasingly a criteria of travel choices. (Phan, T.K.L, 2010).

In practical terms, the concept of eco-branding was implemented at the regional level in Denmark and Sweden (eco-positioning of Copenhagen and Malmö), Spain (Barranca del Rio Santiago), eco-resort «Ecopod» in the Scottish Highlands. The question of what makes a territorial or destination brand into an eco-brand, is now the subject of a lively debate among urban practitioners, but the scientific community hardly raises this issue. The situation is exacerbated by the idea of the apriority of environmental friendliness of the national park brand as a nature reserve.

Therefore, the identification of possibilities of application of the concept of eco–brand regarding the branding of national parks not only as ecological territories but also as special tourist destinations of Ukraine is extremely relevant.

In this context, the objectives of this article are:

- to define the essence of the concept of the "eco-brand" in relation to nature reserves;
- to analyze the material and intangible components of the brands of the national parks of Ukraine, their current market positioning;
- to develop proposals for the formation of eco-brands of separate NPs.

Materials and methods of investigations.

The methodology of the study included a visual comparative analysis of the logos of 44 national parks in Ukraine; content analysis of digital information platforms on which the national parks of Ukraine are represented, including tourist topics; a survey of 87 representatives of the target market of ecological tourism in Ukraine concerning their perception of the tourist product of Ukrainian National Tourism and identification of logos by the hiding place tests; interviewing 8 experts of the market of ecological tourism, including by the association method, to determine the current and future positioning of the Ukrainian NPs.

Results.

Currently, 1,111,600 hectares, or 1.84 % of the area of Ukraine, are classified as national parks – environmental, recreational, cultural and scientific and research institutions of national importance – established for the purpose of preserving, reproducing, and effective use of natural complexes and objects with special environmental, health, historical, cultural, scientific, educational, and aesthetic value (Law of Ukraine «On the Natural Reserve Fund of Ukraine»). «The creation of conditions for organized tourism, recreation, and other types of recreational activities in natural conditions while respecting the regime of protection of protected natural complexes and objects» is one of the tasks of the National Natural Park according to Ukrainian Law.

The State Strategy for Regional Development of Ukraine for 2021-2027, approved by the Cabinet of Ministers of Ukraine on August 5, 2020, № 695, defines tasks in the direction of «Formation of a network of protected areas, conservation, and reproduction of ecosystems, improving the environment» (4) stimulating the economic environment and the development of employment around protected areas, including the definition of an economic mechanism to stimulate the creation and preservation of protected areas; (9) expansion of the network of tourist routes and trails within the territories and objects of the nature reserve fund of Ukraine with the use of interactive methods; (10) promoting public awareness of ecosystem services, including recreational and educational services, which are available in protected areas, with aim of developing related business, and as the part of the task in the field of «Development of domestic tourism» – (14) promoting the formation of regional tourism brands and their promotion within the country and in the international arena, including using modern digital and network technologies (Strategy).

For the 52 national natural parks (NNP) of Ukraine this means the necessity of tourist product improvement, activation of marketing activities, including the development of branding strategies. Currently, 47 out of the 52 NNPs in Ukraine are characterized by the presence of certain signs of the brand`s material component – logos, symbols, colours, elements of presentation design, but none of them has a holistic identity.

At the first stage of the study, the content analysis of websites of national nature parks (NNPs) of Ukraine was done, as they are the main sources of the brand`s material component, in order to determine their self-positioning. The analysis showed that the structure of the websites and textual content of 35 NNPs out of 38 that have a website («Azov-Sivas», «Holy Mountains», «Meotida», «Nobel», «Dvorichansky», «Sinogora», «Beloozersky» , «Kreminski Lisi», «Boykivshchyna», «Zalissia» do not have a website, while «Kamyanska Sich», «Khotynsky» use pages on social networks for this purpose), are quite standard, formal and do not reflect the specifics of the institutions. This means that the most important marketing tool of most NNPs does not fulfill its direct task (the park positioning) and does not apply to the target market. The language of the sites can be described as official, the content is poorly optimized in the searching system. Often the reason for creation of the park , its main tasks are reflected only in the constituent documents and are not obvious for visitors. In fact, the parks features that could become the basis of brands are hidden in the structural components of «Flora», «Fauna», «Landscapes», etc., the texts of which are written in a scientific style. The tourist component of the NNP activity is usually reflected in the sections of websites dedicated to tourist routes, eco-trails and recreational areas. Only there can a potential visitor find information about the park`s features, and therefore the reason for the visit. Exceptions are NNP «Podilski Tovtry» and Carpathian NNP, whose websites are the most customer and business oriented and least formal, obviously aimed at attracting visitors. A sign of an effective marketing policy of national parks is also the availability of information about the activities of visitor centers, which obviously perform the functions of the Destination Marketing Organization.

In order to formalize the results, the NNP websites were evaluated on a 5-point system from four positions: (1) the target audience orientation; (2) the orientation of the text content of the website to visitors; (3) attractive visual content; (4) attractive design that reflects the environmental friendliness of the object (Table 1).

The visual comparative analysis of the logos of national parks of Ukraine conducted at the second stage of the research revealed that the graphic and colour components of their logos quite accurately reflect the specifics of institutions and their assets, such as typical landscapes, hydrological objects, flora, and fauna, etc. Almost all of the studied logos are made in natural colours (table 2) and can be assessed as ecological. At the same time, almost all logos do not correspond to the modern trends of graphic design. They are overloaded with images and meanings and often are extremely similar to each other, which clearly complicates identification. The logos of Verkhovynsky National Park and Skole Beskydy; «Synevyr» and «Holy Mountains»; «Kremenets Mountains», Carpathian and Shatsk NNP substantially repeat each other, and some symbolic images are duplicated.

The method of penetration tests used in the survey of representatives of the target market of ecological tourism (the sample included 87 people aged from 20 to 55 years who travel at least twice a year and determine the motive for their trips as gaining an idea of natural and cultural and ethnographic features of the area), showed that the target audience does not identify logos with specific environmental objects. However, based on their own tourism experience, the respondents made reasonable assumptions about the logo of some NNPs. For example, most such speculations were made about logos depicting a bear («somewhere in the Carpathians»), a dolphin ("connected to the sea") and river valleys (mostly respondents fluctuated between the Dniester and the Southern Bug).

Among the 44 proposed names of NNPs, respondents named only 10 («Carpathian», «Shatsky», «Podilsky Tovtry», «Bug Guard», «Synevyr», «Oleshkivsky Sands», «Holy Mountains», «Holosiivsky», «Dniester Canyon» , «Kremenets Mountains») as well known. 81% of respondents visited NPP «Karpatsky», «Synevyr» – 79%, «Shatsky» – 78%, «Goloseevsky» – 75%, «Bug Guard» – 49%, «Holy Mountains» – 32%, «Kremenets Mountains» – 21%, «Podilski Tovtry» and «Oleshkivski Pisky» – 17% each, «Dniester Canyon» – 7% of respondents. A significant percentage of respondents visited some NNPs without associating them with a specific type of protected area.

This applies to the above–mentioned ten NNPs, as well as to the parks «Dzharilgatsky», «Azov-Sivasky», «Beloberezhya Svyatoslava», «Hetmansky»,

Table 1. Rating of customer orientation parameters of websites of national natural parks of Ukraine

The name of national nature park	Navigation	Text content	Visual content	Design	The name of national nature park	Navigation	Text content	Visual content	Deign
Getmanski	2	1	4	4	«Goloseevsky»	3	4	5	4
Ichnianski	1	1	2	1	«Hutsulshchyna»	3	4	5	5
Carpathian	5	4	5	4	«Tsumanska Pushcha»	4	3	3	4
Dermansko-Ostrozky	4	3	4	3	«Desnyansko–Starogutsky»	4	3	3	3
Mezynsky	4	3	4	4	«Dzharilgatsky»	3	3	2	3
«Bug Guard»	5	4	5	5	« Dniester Canyon»	2	2	2	3
«Great Meadow»	1	1	1	1	«Carmelite Podillya»	3	3	4	4
«Verkhovyna»	3	3	3	3	Kremenets Mountains	3	5	5	5
«Vyzhnytskyi»	1	1	1	1	«Galician»	4	4	3	4
«Cheremosky»	1	2	2	2	«Slobozhansky»	3	3	4	4
«Shatsky»	1	2	5	5	«Tuzla estuaries»	3	3	4	4
«Nizhnosulsky»	1	3	3	4	«Lower Dnieper»	3	4	4	3
«Oleshkiv sands»	2	2	4	3	«Gomilshansky forests»	4	5	2	2
«Pyriatynsky»	4	3	5	5	«Lower Dniester»	1	1	2	2
«Northern Podillya»	1	2	1	4	Uzhansky	5	3	3	4
«Podilsky Tovtry»	4	4	5	5	Yavorivsky	3	3	3	3
«Pripyat-Stokhid»	4	3	5	3	«Skole Beskids»	4	4	3	3
«Synevir»	3	2	3	3	«The Enchanted Land»	1	2	2	2
«Small Polissya»	1	3	4	4	«White Coast of Svyatoslav»	3	3	3	3

«Verkhovynsky», «Vyzhnytsky», «Hutsulshchyna», «Pyryatynsky», «Khotynsky», «Tuzla Estuaries», «Magic Harbor», «Cheremosky», «Uzhansky», «Priazovsky», «Yavorivsky», «Skolivsky Beskids», «Enchanted Land», «Small Polissya», «Slobozhansky», which clearly testifies to the weakness of the brands of the mentioned NPP institutions, the lack in the minds of visitors of the connection between the destination and its ecotourism specialization.

The names of many NNPs are associated exclusively with geographical names («Ichnyansky», «Dermano-Ostroh», «Desnyansko-Starogutsky», «Lower Dnieper», «Lower Suldrovsky», «Pyriatynsky», «Northern Podillya», «Pripyat-Stokhid»); famous names («Carmelite Podillya»), tourist sites («Kamyanska Sich», «Mezynsky»). Respondents recognize only certain markers indicated in the names of the parks, but do not show interest in visiting. The level of awareness of respondents about the six NNPs (Tsumanska Pushcha, Velykyi Luh, Dvorichansky, Meotida, Nobelsky, Gomilshansky Forests), and therefore the desire to visit them, was zero.

The results of the survey allowed us to position the NNP of Ukraine according to the criteria of «reputation among target markets» and «attendance» (Table 3).

As shown in the table, the intentions of potential consumers to visit directly depend on the level of awareness of tourists, and therefore on the marketing policy of the parks.

Elements of the traditional method of associations for branding research were used in the survey. According to it, respondents named associations that are associated with the attractiveness of these NRF objects. These associations could include natural sites (landscapes, hydrological sites, representatives of flora and fauna), place names, cultural and historical sites, including events that take place on the territory of the NNP, as well as celebrities whose names are associated with the territory.

The study showed that currently the strongest positioning is that of the Shatsk NNP, which is clearly associated with the lake Svityaz, eel fish, Ukrainian Polissya as such. At the same time, if the positions of Shatsk NNP have been determined historically, then the strong positioning of NNP «Podilski Tovtry» is the result of special marketing efforts.

Specially created messages (such as «there are similar geological structures of relief only in the USA and Great Britain; Podilsky Tovtry Park is the largest in Europe; the highest bridge in Ukraine for bungee jumping is in Kamyanets-Podilsky; Atlantis

Table 2. Logos of national natural parks of Ukraine

NNP «Getmanski»	NNP «Desnyansko-Starogutsky»	NNP «Podilsky Tovtry»	NNP «Mezynsky»	NNP «Hutsulshchyna»	NNP «White Coast of Svyatoslav»
NNP «Ichnianski»	NNP «Dzharilgatsky»	NNP «Pripyat-Stokhid»	NNP «Holy Mountains»	NNP «Khotyn»	NNP «Bug Guard»
NNP «Carpathian»	NNP «Tuzla Estuaries»	NNP «Synevir»	NNP «Carmelyukove Podillya»	NNP «Vyzhnytskyi»	NNP «Great Meadow»
NNP «Tsumanska Pushcha»	NNP «Kamyanska Sich»	NNP «Slobozhansky»	NNP «Kremenets Mountains»	NNP «Dniester Canyon»	NNP «Verkhovyna»
NNP «Magic Harbor»	NNP «Oleshkiv Sands»	NNP «Dvorichansky»	Yavorivsky NNP	NNP «Lower Dnieper»	Lower Dniester NNP
NNP «Cheremosky»	NNP «Pyriatynsky»	NNP «Dermansko-Ostrozky»	NNP «Skole Beskids»	NNP «Nizhnosulsky»	NNP «Golosiivsky»
NNP «Meotida»	NNP «Northern Podillya»	Shatsky NNP	NNP «Galician»	NNP «Gomilshansky Forests»	NNP «The Enchanted Land»

Cave is the only one in Khmelnytsky region, which has 3 tiers») can become a model of positioning for other parks. The position of the «Holy Mountains» National Nature Park is clearly defined, but only due to the presence of the Holy Dormition Svyatogorsk Lavra on its territory and the chalk landscape, which is much praised in the media.

The group of NNPs located in the Ukrainian Carpathians is also in one way or another associated with this physical-geographical area. The Carpathian NNP, the Verkhovyna NNP, the Hutsulshchyna NNP, the Synevir NNP, and to a much lesser extent the Uzhansky, Vyzhnytskyi, Cheremosky NNPs, and the Skolivsky Beskydy NNP are currently connected not only with the Carpathians themselves but also with hydrological objects (Lake Synevyr, the Vyzhnytsia River, and the Cheremosh River); the brown bear, whose image has also recently been associated with the region; trout ; edelweiss flowers and red rue; the culture of the Hutsuls and other ethnic groups.

Table. 3. Positioning of NNP of Ukraine according to the criteria «the level of awareness» and «the probability of attendance»

The level of awareness of the target market						
High	–	–	–		«Holy Mountains»	«Carpathian, Shatsky»
Above average	–	–	–	«Dzharilgatsky», «Bug Guard»	«Oleshkivsky Sands», «Kremenets Mountains»	«Hutsul region», «Verkhovyna», «Synevyr»
Average	«Mezinsky»	–	–	«Lower Dnieper», «Dniester Canyon», «Podilsky Tovtry», «Skoliv Beskids»	«Golosiivsky», «Tuzla Estuaries»	–
Below average	–	–	«Lower Sula», «Khotyn», Lower Dniester, Priazovsky	«Cheremosky»	«Vyzhnytskyi »	–
Low	«Dvorichansky», «Pyryatynsky», «Karmelyukove Podillya», «Halytsky»	«Meotida», «Dermansko–Ostrozky», «Northern Podillya», «Small Polissya», «Gomilshansky Forests»	«Desnyansko–Starogutsky», «Yavorivsky», «Pripyat–Stokhid», «Slobozhansky»	Azov–Sivasky	Uzhansky	–
Null	Ichnyansky, «Magic Harbor», «Nobel», «Great Meadow»	«Tsumanskaya Pushcha», «Svyatoslav's White Coast», «The Enchanted Land»	Hetmansky, «Kamyanska Sich»	–	–	–
	Null	*Low*	Average	*Above average*	*High*	*Occurred*
	Probability of visiting the NNP					

Importantly, the identification of Carpathian national parks within the group is often quite vague – if Synevir Park is associated with the lake of the same name, the positions of the other parks are not differentiated.

The positions of the next group of national nature parks have been identified in the minds of target audiences quite recently and are now quite strong – NPP «Dzharilgatsky» (spit of the same name, dolphins), «Oleshkiv Sands» (semi–desert landscape), «Dniester Canyon» (canyon), «Bug Guard» (Migiy Rapids).

The positioning of the rest of the NNPs of Ukraine is associated exclusively with the words in the name, and not with the features of the parks. Thus, Azov–Sivasky, Priazovsky, Nizhnedneprovsky, Nizhnednistrovsky, Nizhnosulsky, Holosiyivsky, Dermansko–Ostrozky, Desnyansko–Starogutsky, Yavorivsky, Ichnyansky, Pyryatynsky NNP, as well as NNP «Northern Podillya», «Small Polissya», «Slobozhansky», «Khotynsky», «Pripyat–Stokhid», «Kremenets Mountains» are associated exclusively with toponyms that sound in the name; NPP «Meotida» – with Ancient Greece, NPP «Karmelyukove Podillya» and «White Coast of Svyatoslav» – with the corresponding characters. Other nature parks do not evoke any lasting associations in potential visitors.

Thus, it is possible to state with confidence that the specifics of most national parks in Ukraine nowadays are incomprehensible to tourists, and their perception is largely unrelated to the ecological dominant. The main activities of parks, protected landscapes, natural monuments, flora, and fauna remain available for understanding only by a narrow circle of specialists.

Interviews with 8 experts of ecological tourism were aimed at determining the existing and potential positions of NNP brands in Ukraine, as well as the strengths and weaknesses of their marketing strategies. Tourism specialists, familiar with the specifics of all NNPs of Ukraine were selected for the in-depth interviews. During the interviews, the experts named the main expectations for visiting the parks for the target market, as well as the features of the NNPs that could become the basis of tourist brands in the future. It is worth noting the high level of coincidence between the associations obtained during the survey of visitors and the typical expectations cited by experts as reasons for travel.

The proposals of experts on the long-term positioning of the NNPs of Ukraine are given in Table 4 (while preserving the vocabulary of experts).

The interview also showed those aspects of the activities of national nature parks of Ukraine, which could, in the long run, become the basis of their branding as objects of the nature protection fund, to fix the territories in the minds of consumers in the context of clear symbols. It is worth noting that positioning the national nature parks within the concept of eco-branding, experts emphasized such objective features as landscape features, unique natural objects, rare species of flora and fauna, etc. There were also those activities in the parks that could be perceived by the target market as benefits from visiting: escape from everyday life; photography; a place for a weekend; fishing; some sports activity; observation of birds, animals or natural phenomena. 5 of the 8 experts noted that reminding visitors about the "ecological purity" of the landscape or some individual components, the healing properties of air, water, etc., the mythologizing of the area arouse additional interest from visitor`s side.

But, even the presence of strong material components of the brand, expressed in effective positioning, does not make the brand of the national nature park an eco-brand. The analysis of the concept of eco-branding of individual territories of Europe allowed one to adapt their basic principles to the specifics of the national nature park. Thus, the generalization of concepts shows that at the territorial level the traditional components of the brand should be supplemented by three components: ecological landscape-spatial design, the formation of ecological models of human behaviour within the territory, and the application of the ecological approach in facility management (Stefan Anderberg, Eric Clark, 2013). Each of these components can be applied to the national nature park, which will enhance the environmental friendliness of the brand. Thus, the National Parks Service of USA (NPS) has developed national park design standards, which include Architectural, Automated Controls, CAD & Drafting, Civil (Site) & Environmental Engineering, Cost Engineering & Estimating, Electrical Engineering, Fire Protection Engineering, Landscape Architecture standards. Lighting, Mechanical Engineering, Occupational Health & Safety, Engineering, Structural Engineering, Sustainability (https://www.nps.gov). In addition, the organization is guided by a special policy document the NPS Management Policies (The Guide to Managing the National Park System, 2006), which includes sections on the management of cultural resources, management of natural resources, use of parks and park structures, and many others, many of which directly affect the design and construction of facilities. Regarding the formation of ecological models of behaviour, some interesting concepts of eco-tourism management, including the concept of Limits of Acceptable Changes (LAC), Recreation Opportunity Spectrum (ROS), Visitor Experience and Resource Protection (VERP), Recreational Impact Management (VIM), Tourism Optimization Model (TOMM), Tourism Futures Simulator (TFS), etc., are developed and implemented in differ-

Table 4. Proposals for long-term positioning of national natural parks of Ukraine

Name of NPP	Natural objects	Anthropogenic objects
1	2	3
Azov-Sivasky NPP	Oz. Sivash, the islands of Churyuk and Kuyuk-Tuk	-
Hetman NNP	Vorskla River Valley, bird common crane	Hetman's capital
Ichnia NNP	Valley of the Uday River and Ichenka	Ichnia ceramics
Carpathian NNP	Waterfalls, lakes Maricheyka and Nesamovyte, rocks and caves Dovbush Hoverla mountains, Pip Ivan, Hamster, Rudyak swamp, Kedruvate tract, rhododendron plant (red root)	Hutsul culture
NPP «Tsumanskaya Pushcha»	Bison animal, tract «Devil's swamp», peat mud and mineral waters, oak forests	Heritage of the Radziwills
Mezynsky National Nature Park	Desna River Valley, Khotyn Lakes and Horseshoe Happiness, Tsar-Oak	Spruce Alley Mezynsky Archaeological Site, Palace
NPP «Holy Mountains»	Cretaceous landscapes, plant tulip, animal ermine, bird eagle owl, tract «Mayatskaya dacha»	Holy Dormition Svyatogorsk Lavra
«Svyatoslav Beloberezhya» National Park	Kinburn Spit and Solonets-Tuzla Lakes, orchid fields, sand dunes; alder, birch and oak nuts - sagas.	Sviatoslav the Brave, the cult of Achilles
NPP «Buzky Gard «	Gard and Protych tracts, Mygiivsky Canyon, the mouth of the River Velyka Korabelna, Arbuzynsky, Aktovsky and Petropavlovsky granite massifs	Herodotus, Exampey - a sacred way, the Cossacks
NPP «Great Meadow»	Plavni Dnieper, archipelago «Big and Small Kuchugury» and floodplain «Seven Lighthouses», riparian forests	Cossack winterers, the capital of the Golden Horde the city of Gulistan

Continuation of Table 4. Proposals for long-term positioning of national natural parks of Ukraine

1	2	3
NPP «Skolivsky Beskydy»	Animals bison and beaver, waterfall on the river Kamyanka, lake. Zhuravlyne, «Iron Water»	Boykivska culture, fortress «Tustan»
NPP «Enchanted Land»	Rare forms of rock relief, virgin beech forests, volcanic ridge, rivers Latorytsia and Borzhava, sphagnum swamp «Black Swamp»	-
NPP «Gomilshansky For-ests»	Valley Seversky Donets, lake. White, Cossack Mountain	Korobovi Khutory
NPP «Shatsky»	Lake Svityaz and other lakes, fish, eel	-
NPP «Male Polissya»	Gorin River Valley, Holy and Blue Lakes, peat bogs	Ruins of the palace and castle, Izyaslav
NPP «Verkhovynsky»	White and Black Cheremosh, mineral waters , village. Burkut, group of rocks «Stone Baba»	Hutsul culture, «Shadows of forgotten ancestors», molfars
«Vyzhnytskyi» NNP	Nimchych Pass, Lekechensky Rocks, Dzherela Luzhky and Byk, cascade of waterfalls of Mala Vyzhenka River, Stizhok tract, Dovbush Cave	Jewish Synagogue, Yu. Fedkovych, N. Yaremchuk I. Mykolaychuk
NPP «Halytsky»	Halychyna caves, underground rivers and streams, limestone rocks, Halych Hora	-
NPP «Goloseevsky»	Centennial oaks	Museum of Architecture and Life , Observatory
NPP «Hutsulshchyna»	Oz. Lebedyn	Hutsul culture
NPP «Dvorichansky»	Cretaceous landscapes, animal marmot , peony valley, riparian forests	-
NPP «Dermansko-Ostrozky»	Biird black stork , plants orchid	Ostrog, castle ruins
Desnyansko-Starogutsky National Nature Park	Desna River Valley, Starogutsky Forest	Partisan Movement
NPP «Dzharilgatsky»	O. Dzharilgach, 200 lakes, dolphins and marine fauna	Achilles cult, old lighthouses
NPP «Dniester Canyon»	Dniester Canyon, Dzhurinsky waterfall, caves «Optimistic», «Blue Lakes», «Crystal», «Mills», «Verteba»	Palace and castle complexes
NPP «Kamyanska Sich»	Steppe landscapes, the valley of the Dnieper	Kamyanska Sich
NPP «Karmelyukove Podillya»	R. Savranka, orchids, Mediterranean forests	Ustym Karmalyuk
NPP «Kremenets Mountains»	Little Carpathians	Kremenets-Pochaiv State Historical and Architectural Reserve
NPP «Meotida»	Bilosarai Spit and «Polovtsian Steppe», Crooked Spit	Culture of the Golden Horde and the Crimean Khanate
NPP «Lower Dnieper»	Delta of the Dnieper, floodplains	-
NNP «Nizhnosulsky»	Valley of the River Sula	-
NPP «Nobelsky»	Lakes Nobel , Mill	Narrow gauge railway
NPP «Oleshkiv Sands»	Desert and semi-desert landscapes, dunes, mounds, dunes, the largest semi-desert in Europe	-
NPP «Pyriatynskyi»	Udai River Valley, Berezova Rudka	Park Burty Tract
NPP «Northern Podillya»	Sources of the rivers Styr, Western Bug, Seret, rocks «Trinig», «Dead head», stone «Executioner»	Castles, black-smoked Gavaret ceramics
NPP «Podilski Tovtry»	Atlantis Cave, Kitaygorodskoe Outcrop, Smotrytsky Canyon, meanders of the Smotrych and Ternava rivers, mineral springs, Bakot Bay, Tovtrov Range - Remains (strands and atolls) of the Coral Reef of the Sarmatian Sea	National Historical and Architectural Reserve «Kamyanets», Ustym Karmalyuk
NPP «Pripyat-Stokhid»	Valleys of the river Pripyat and Stokhid «Ukrainian Amazon»	Authentic Ukrainian village Svalovychi
NPP «Synevir»	Lake Synevir, Gregoty Brown Bear Rehabilitation Center	Museum of log rafting on the Ozeryanka River

Continuation of Table 4. Proposals for long-term positioning of national natural parks of Ukraine

1	2	3
NPP «Slobozhansky»	Sphagnum bogs, relict lakes	Sharivsky Palace
NPP «Tuzlovsky Estuaries»	Estuaries and lakes Shagany, Alibey, Burnas, Magalevskoe, Martaza, Buduri, Karachaus, Hadzhider, Kurudiol, Solony, Dzhansheysky and Maly Sasyk, a nesting place of birds, pelicans, animal dolphin	Tuzliv Amazonia
NPP «Khotyn»	Dniester Walls, Tovtrov Range - Remains of the Coral Reef of the Sarmatian Sea, Caves and Waterfalls of Karst Origin	Khotyn Fortress
NPP «Cheremosky»	Mount Tomnatyk, Sokil rocks The confluence of the Perkalab and Saratatya rivers	Pamir Military Base Gates of the Sarata River
Lower Dniester NNP	Area between the Dniester and Turunchuk rivers, floating land, animals,deer and mouflon, bat colony, plantation of yellow pitchers	Dniester
Priazovsky NNP	Estuaries Molochny, Utlyuksky, braids (Fedotova, Stepanovskaya, Berdyanskaya), plants Schrenck's tulip, iris, hyacinth	-
Uzhansky NPP	Mineral springs, «Dido Dub», virgin beech forests, Knyagininsky meteorite	6 old wooden churches of the XVII-XVIII centuries.
Yavoriv National Nature Park	Roztochchya, watershed of the Black and Baltic Seas, animal tarpan	Yavoriv toy, Krekhiv Monastery

ent counties and could also be used in domestic NNP. Such activities could help to form their eco-brands.

Conclusion.

Eco-branding of the national park as a tourist destination plays an important role in the process of forming its attractiveness for growing target segments focused on the consumption of environmental friendliness as an unconditional value. In the case where the object of branding is a national nature park or any other nature conservation object, the intangible elements of the brand must be based on eco-friendliness, and the material ones must reflect this primary value. It is obvious that the environmental friendliness of the brand as such may not lead to the desired effect - of increasing the attractiveness of the object if the brand itself does not reflect its authenticity, does not cause a potential visitor constant association, the desire to gain unique experience, does not help identify and differentiate, is not replicated by different communication platforms. The development of a national nature park in the concept of an eco-brand also means the introduction of environmental standards of landscape design, appropriate models of behaviour, and management approaches. National natural parks of Ukraine are currently in the first stage of forming their own eco-brands. Despite the presence of certain elements of brand identity, there is a lack of targeted marketing activities, lack of positioning, and, consequently, a low level of awareness of target audiences about the activities of most of them. Therefore, the development of their brands in a holistic environmental concept can be considered the immediate task for each of them.

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Dynamics of snow cover in Kirovohrad region at the end of the XX and the beginning of the XXI centuries

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Abstract. Snow cover significantly affects the formation of climate in winter. The snow cover has low thermal conductivity, which protects the soil from freezing. In the spring, the snow cover significantly moistens the soil and plays an important role in the surface water regime and in the economic activity of the country. It should be noted that the lack or insufficient height of snow cover can be the cause of freezing of winter crops and their death, which leads to a decrease and even loss of yield. Accordingly, the increase in crop yields depends on the proper use of snow cover. The purpose of the research is to determine the characteristics of the snow cover and analyze their changes in Kirovohrad region in the late twentieth and early twenty-first centuries. Data of daily observations of snow cover at meteorological stations of Kirovohrad region for the period from 1996 to 2018 were used as primary information in the work. It is established that the appearance of snow cover at the stations of Kirovohrad region coincides in two periods (1961-1990 and 1996-2018) and was observed in the third decade of October at almost all stations, except for the area of data distribution of Dolynska weather station, where the first appearance of snow cover during 1961-1990 occurred in the first decade of October. The disappearance of snow in this period was observed in the third decade of April, in contrast to data from the climate cadaster, where 75% of stations observed snowmelt in the second decade of April, while at Dolynska station in the south of the region snowmelt occurred in the third decade of March. At Kropyvnytskyi station, located in the central part of Kirovohrad region, the appearance and disappearance of snow cover was observed in both periods on the same dates. In the period 1996-2018, the values of the highest decadal peaks for the winter were lower than in the climatic norm. The frequency of winters with the highest decadal height of snow cover in different gradations varies greatly in the study periods. For 1996-2018, the maximum was observed in the gradation of 1-5 cm; in the climatic norm the greatest recurrence is recorded in the gradation of 11-20 cm, significant indicators are observed in the gradation of 21-30 cm. The maximum recurrences of the decadal height of the snow cover are 100% and are determined in the gradation of 0-5 cm in both periods of snow cover.

Keywords: *snow cover, decadal altitude, spatial variability, time distribution, repeatability*

Динаміка снігового покриву на території Кіровоградської області наприкінці XX та на початку XXI століть

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Анотація. Сніговий покрив істотно впливає в зимовий період на формування клімату. Сніговий покрив має малу теплопровідність, чим зберігає грунт від промерзання. Навесні сніговий покрив суттєво зволожує грунт і грає важливу роль в режимі поверхневих вод і в господарській діяльності країни. Необхідно зазначити, що відсутність чи недостатня висота снігового покриву можуть бути причинами вимерзання озимих посівів та їх загибелі, що зумовлює зниження, і, навіть, втрату врожаю. Відповідно, збільшення врожайності сільськогосподарських культур залежить від належного використання снігового покриву. Метою наукового дослідження є визначення характеристик снігового покриву і аналіз їх змін на території Кіровоградської області наприкінці XX та на початку XXI століть. В якості вихідної інформації в роботі використовувалися дані щоденних спостережень за сніговим покривом на метеорологічних станціях Кіровоградської області за період з 1996 по 2018 роки. Встановлено, що поява снігового покриву на станціях Кіровоградської області співпадає за два періоди (1961-1990 і 1996-2018 рр.) й спостерігається в третій декаді жовтня майже на всіх станціях, винятком є район поширення даних метеостанції Долинська, де поява снігового покриву у період 1961-1990 рр. відбувається в першій декаді жовтня. Схід снігового покриву в цей період відзначається в третій декаді квітня на відміну від даних кліматичного кадастру, де у 75 % станцій сходження снігу відмічається у другій декаді квітня, а на станції Долинська, що знаходиться на півдні області, схід снігу відбувся взагалі в третій декаді березня. На станції Кропивницький, що знаходиться в центральній частині Кіровоградської області, поява і схід снігового покриву відзначається в обидва періоди в ті ж дати. У період 1996-2018 рр. значення найбільших за зиму декадних висот менші, ніж у кліматичній нормі. Повторюваність зим з найбільшою декадною висотою снігового покриву у різних градаціях дуже різниться в досліджуванні періоди. Для 1996-2018 років максимум спостерігається в градації 1-5 см; у кліматичній нормі найбільшу повторюваність зафіксовано у градації 11-20 см, значні показники відмічаються і в градації 21-30 см. Максимальні повторюваності декадної висоти снігового покриву дорівнюють 100 % і визначені в градації 0-5 см в обох періодах на початку й наприкінці періоду зі сніговим покривом.

Ключові слова: сніговий покрив, декадна висота, просторова мінливість, часовий розподіл, повторюваність

Introduction.

The cold period of the year is characterized by snowfall in the whole territory of Ukraine. In some regions of the country, such as the Carpathians and eastern Polissya, stable cover is maintained for a long time and can reach great heights. In the northeast of the Forest-Steppe, the snow cover is also stable, but its characteristics change rapidly towards the south. In the steppe zone of Ukraine and in its extreme south, a stable snow cover is established in some years and persists for a short period of time. The first snow at the beginning of winter in the country doesn't hold due to the peculiarities of the thermal regime during this period. And subsequent precipitation in the form of snow forms a snow cover which has stable characteristics. An important parameter of snow cover is the nature of its occurrence. A large number of factors depend on the occurrence of snow: air and soil temperature, depth of soil freezing, soil moisture and more. The nature of snow, periods of its formation and dissipation for different regions of Ukraine differ significantly and depend on the terrain, vegetation, circulation, temperature, precipitation, wind, blizzards and more (Handbook of Climate of the USSR, 1969; Lebedenko, 2019).

Kirovohrad region is located in the forest-steppe and steppe physical-geographical zones in central Ukraine, on the interfluve of the Dnieper and the Southern Bug. Agrometeorological, climatic and soil features of the territory are quite favourable for the development of agriculture. The study region lies in the south of the Dnieper Upland. It is a plateau or elevated plain with a dense network of river valleys, ravines and gullies. Kirovograd region is characterized by a temperate continental climate and from southwest to the northeast there is a band of high atmospheric pressure. To the north of it moist air masses spreading from the Atlantic dominate , to the south - continental air masses. Winter is mild and characterized by frequent thaws. The northern and north-western parts of the region lie in a warm but not sufficiently humid agro-climatic zone,; the eastern and southern parts are in a very warm and arid zone. Snow cover is usually formed in the third decade of November, and disappears in the second decade of March (Encyclopedia of Modern Ukraine, http://esu.com.ua/search_articles.php?id=7021; https://uk.wikipedia.org) .

Snow cover significantly affects the formation of climate in winter. The radiation balance of the underlying surface decreases with the appearance of cover, as snow has significant radiation and reflective properties, which leads to cooling of the surface and air (Aoki, Hachikubo, Hori, 2003). Such characteristics of the snow cover lead to an increase in relative humidity due to a decrease in its temperature and increased humidity during snow evaporation. The snow cover has low thermal conductivity, which protects the soil from freezing. In the spring, the snow cover significantly moistens the soil and plays an important role in the surface water regime and in the economic activity of the country. It should be noted that the lack or insufficient thickness of snow cover can be the cause of freezing of winter crops and their death. Accordingly, the increase in crop yields depends on the proper use of snow cover (USSR Climate Handbook, 1969; Nedostrelova, Lebedenko, 2018; Lebedenko, Nedostrelova, 2019; Goroshko, 2017). Thus, it is difficult to overestimate the importance of snow cover for agriculture, the economy and ecology of the country. The purpose of the research is to identify the characteristics of snow cover and analyze their changes in Kirovohrad region in the late twentieth and early twenty-first centuries.

Material and research methods.

Data of daily observations of snow cover at meteorological stations of Kirovohrad region for the period from 1996 to 2018 were used as the initial information in the work.

Snow cover is monitored daily, as well as periodically on snow surveys in order to record the amount of snow and water reserves. The term "snow cover" means not only a layer of snow on the surface of the soil, but also layers of ice on the surface of the soil and snow, melted water that appeared under the snow (Instructions, 2011). Observations are carried out at Coordinated International Time at 06 o'clock. Snow monitoring takes place during the season in the presence of snow cover on certain routes. As a result of daily observations, the height of the snow cover on the meteorological site or in the selected area near the station, the nature of the snow cover, the degree of snow cover around the station are recorded in points. The height of snow cover is determined by stationary snow stakes as the distance from the soil surface to the boundary of snow cover-atmosphere, the degree of cover, the nature of the snow and the structure of snow are determined visually in all weather conditions. The degree of cover is determined on a 10-point scale. Assessment of the nature of snow cover is based on the presence of snow drifts, as well as the condition of the soil under the snow cover. (Nastanova, 2011).

Snow cover is characterized by decadal heights, calculated at the beginning and end of winter, when snow cover is observed in 50% of winters and more. Decade height is determined by dividing the total height for all years of the period by the number of years. If snow is detected in less than 50% of winters, the decadal height is not calculated, and in the table of the handbook a mark (•)is put The multiyear height of snow cover is calculated in the same way as by a snow stake. The height of snow cover, as a rule, varies significantly from year to year, which is why the frequency and occurrence of winters with different maximum decadal heights of snow cover is distinguished. Such calculations are performed only for long-range base stations (Vrublevskaya, Katerusha, Myrotvorskaya, 2004; Kornus, Lysenko, 2017; Nedostrelova, Lebedenko, 2019). An important parameter of snow cover is the long-term maximum height for winter, which is calculated by averaging the maximum decadal altitudes, which are selected from each year, regardless of in which decade or month this maximum is recorded. Maximum and minimum decadal heights by months are determined according to data from a fixed snow stake, and in winter such heights are calculated according to the stakes and snow monitoring (Vrublevskaya, Katerusha, Mirotvorskaya, 2004; Nedostrelova, Lebedenko, 2019).

Snow cover is characterized by certain criteria developed according to the GGO method. According to this method, a day with snow cover is considered a day in which at least half of the visible area of the station is covered with snow. Steady snow cover is cover that is observed for at least a month with breaks of no more than three separate days or days in a row, and a break of one day in early winter corresponds to presence of snow cover for at least 5 days, and a longer break is preceded by snow for at least 10 days. Observations of snow cover show that several periods with steady snow cover may form during the winter. If there are no more than 5 days between such periods, the period from the first day with fixed cover to the last day of winter is fixed as a single period. An important characteristic of the established snow cover is the average long-term dates of formation and dissipation. Such dates are calculated when the number of days with snow cover is more than 50% of all winters and only one period with stable snow cover was observed during the winter. If at the end of winter no more than 3 days after the snowmelt, snow cover is formed again which lasts at least 10 days, the period of occurrence is recorded as continuous. All defined dates for each year are entered in the table and determine the average dates, the earliest and the latest (Vrublevskaya, Katerusha, Mirotvorskaya, 2004; Nedostrelova, Lebedenko, 2019).

Results and their analysis.

According to daily observations, the decadal height of snow cover at meteorological stations in Kirovohrad region for the period from 1996 to 2018 was calculated (Table 1, Table 3). To identify changes in the height of snow cover in the study area, two climatic periods were used: the first is 1996-2018, the second is the climatic norm (Climatological Standard Norms, 2002) of 1961-1990 (Table 2, Table 4).

Table 1. Decade height (cm) of snow cover on a permanent snow stake for the period 1996-2018.

Station	X	XI			XII			I			II			III			IV			The greatest for the winter		
	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	aver	max	min
Svitlovodsk	•	•	•	•	2	3	3	4	6	6	6	5	4	5	4	•	•	•	•	11	33	0
Novomyrhorod	•	•	2	4	3	4	6	7	9	11	14	11	10	11	9	4	•	•	•	19	43	0
Znamyanka	•	•	•	4	3	4	5	6	8	11	12	10	8	11	11	5	•	•	•	19	55	0
Kropyvnytskyi	•	•	1	•	2	3	4	6	7	9	9	7	5	7	7	3	•	•	•	15	37	0
Gaivoron		•	•	3	3	5	5	7	9	10	8	10	6	5	3	1	•	•		15	34	0
Pomichna	•	•	•	3	2	3	4	5	8	10	10	8	6	7	6	2	•	•	•	14	31	0
Dolynska		•	•	•	•	3	3	5	6	8	8	8	5	6	5	•	•	•		14	37	0
Bobrynets		•	•	•	•	2	3	6	7	11	9	7	7	10	•	•	•	•		15	39	0

Table 2. Decade height (cm) of snow cover on a permanent snow stake for the period 1961-1990.

Station	X			XI			XII			I			II			III			IV			The greatest for the winter		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	aver	max	min
Svitlovodsk			•	•	•	1	1	3	3	4	6	6	6	7	7	6	3	•	•	•		16	59	6
Novomyrhorod			•	•	•	2	3	5	6	7	9	10	10	12	12	11	7	4	•	•		24	52	4
Znamyanka			•	•	•	2	3	5	5	6	9	10	11	11	12	11	7	4	•	•		24	63	10
Kropyvnytskyi			•	•	•	1	3	5	6	6	9	10	11	12	12	12	8	3	•	•	•	28	61	9
Gaivoron			•	•	•	1	2	3	4	6	8	9	8	9	10	7	5	•	•	•		23	42	6
Pomichna			•	•	•	1	1	3	3	4	6	7	6	6	7	6	4	2	•	•		19	32	6
Dolynska	•		•	•	•	1	2	3	3	3	5	8	8	9	10	8	5	2				18	61	5
Bobrynets			•	•	•	1	2	3	3	4	5	6	6	8	9	7	3	•	•	•		20	55	4

The appearance of snow cover at the stations of Kirovohrad region in the period 1996-2018 was detected from the third decade of October at almost all stations, except for stations Gaivoron, Dolynska, Bobrynets, where the appearance of snow cover occurs in the first decade of November. The disappearance of snow was determined in the third decade of April, with the exception of the stations Gaivoron, Dolynska, Bobrynets (Table 1). The maximum values of the decadal height of snow cover were observed in the first decade of February. They were 14 and 12 cm at Novomyrhorod and Znamyanka stations, respectively. The lowest values of altitude were recorded at the beginning and end of the period with snow cover. For each station, the averages were calculated, the minimum and maximum values of this indicator were identified. The maximum average value for winter - 19 cm was observed at Novomyrhorod and Znamyanka stations, and the minimum - 11 cm at Svitlovodsk station. The minimum value for all stations was 0 cm. The maximum value - 55 cm was recorded at Znamyanka station.

The appearance of snow cover at the stations of Kirovohrad region according to the climatic norm was observed from the third decade of October at all stations, except the station Dolynska, where snow appeared in the first decade of October (Table 2). The disappearance of snow in almost all stations can be traced in the second decade of April, except for Kropyvnytskyi station in the third decade of April and Dolynska station in the third decade of March. The maximum values of the average decadal height of snow cover were observed in the second and third decades of February and in the first decade of March and were 12 cm at the stations Novomyrhorod, Znamyanka and Kropyvnytskyi. The lowest values of altitude were recorded at the beginning and end of the period with snow cover. The maximum average value for winter - 28 cm was observed at Kropyvnytskyi station, and the minimum - 16 cm at Svitlovodsk station. The minimum value of 4 cm was observed at Novomyrhorod and Bobrynets stations. The maximum value - 63 cm was recorded at Znamyanka station.

Table 3. Recurrence (%) of winters with the greatest decadal height of snow cover in different grades for the period 1996-2018.

Station	Height of snow cover (cm)							
	0	1-5	6-10	11-20	21-30	31-40	41-50	51-60
Svitlovodsk	27	48	17	7	1	0		
Novomyrhorod	20	39	12	18	8	2	1	
Znamyanka	24	37	16	15	4	2	2	0
Kropyvnytskyi	28	38	16	14	3	1		
Gaivoron	18	42	22	13	3	2		
Pomichna	24	41	16	14	4	1		
Dolynska	24	44	14	13	3	2		
Bobrynets	30	36	12	13	7	2		

The next characteristic of snow cover, the trends of which were studied for different periods, is the recurrence of winters with the highest decadal height of snow cover in different gradations (Table 3, Table 4). The maximum recurrence was found in the gradation of 1-5 cm at all stations, the highest value of 48% was recorded at the station Svitlovodsk, and the minimum was 36% and determined for the station Bobrynets. Also, a significant number of cases were observed for the height of 0 cm: a maximum of 30% was detected at the station Bobrynets, a minimum of 18% is characterized by the station Gaivoron. At all stations, in almost 100% of the winters height of snow cover ranged from 0 to 40 cm. And only for Novomyrhorod and Znamyanka stations was the recurrence value 1-2% for heights of 41-60 cm.

observed at the stations Znamyanka, Kropyvnytskyi and Dolynska, in contrast to the period 1996-2018, when such heights were not detected at all.

The characteristic of snow cover can be also the indicator of recurrence of decadal height for decades , which is shown in tables 5-20 for different periods. Analysis of this parameter for Svitlovodsk station (Table 5) shows that the highest recurrence values were observed in the gradation of 0-5 cm in the third decade of October, in the first and second decades of November and in the first and third decades of April. They are 100%. In the gradation of 6-10 cm, the maximum recurrence was recorded in the third decade of November - 33%. The maximum recurrence in the gradation of 11-20 cm - 20% of cases , was observed in the third decade of January and in the first decade of March . The highest recurrence - 9% in the gradation of 21-30 cm was observed in the first decade of February. It should be noted that the value of height in the gradation of 31-50 cm was recorded only in the second decade of February, when the recurrence was 5%. The appearance of snow cover was observed in the third decade of October, and the disappearance was detected in the third decade of April.

Table 4. Recurrence (%) of winters with the highest decadal height of snow cover in different grades for the period 1961-1990.

Station	Height of snow cover (cm)								
	0	1-5	6-10	11-20	21-30	31-40	41-50	51-60	61-70
Svitlovodsk			35	49	10	3		3	
Novomyrhorod		3	3	42	25	14	10	3	
Znamyanka			10	28	53	3		3	3
Kropyvnytskyi			14	14	39	17	10	3	3
Gaivoron			14	34	28	21	3		
Pomichna			14	45	31	10			
Dolynska		4	17	50	17	8			4
Bobrynets		3	3	63	10	18		3	

In the period 1961-1990, the maximum recurrence was found in the gradation of 11-20 cm in 75% of stations in the study region, the highest value of 63% was recorded at Bobrynets station, and the minimum was 14% determined for Kropyvnytskyi station. Also, a significant number of cases were observed for heights of 21-30 cm: a maximum of 53% was detected at Znamyanka station, a minimum of 10% at Svitlovodsk and Bobrynets stations. The maximum gradation of 61-70 cm, which records a recurrence of 3-4%, was

According to the climatic cadastre, the appearance of snow cover at the Svitlovodsk station (Table 6)

Table 5. Recurrence of the decadal height of snow cover by decades at the Svitlovodsk station for the period 1996-2018 (%)

Gradation	X	XI			XII			I			II			III			IV		
	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0-5	100	100	100	67	85	81	75	67	60	66	59	76	72	67	72	91	100		100
6-10				33	15	19	25	22	25	14	27	9	11	13	14	9			
11-20								11	10	20	5	5	17	20	14				
21-30									5		9	5							
31-50												5							

Table 6. Recurrence of the decadal height of snow cover by decades at the Svitlovodsk station for the period 1961-1990 (%)

Gradation	X	XI			XII			I			II			III			IV	
	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
0-5	100	100	100	100	100	82	75	84	70	62	68	58	56	57	79	75	100	100
6-10						11	14	4	21	26	21	19	16	17	5	17		
11-20						7	11	4	3	4	7	15	20	17	5	8		
21-30								4	3	4		4	8	9	11			
31-50								4	3	4	4	4						

was detected in the third decade of October, as in the period 1996-2018. The disappearance was observed in the second decade of April, which occurred a decade earlier than in the first period. The analysis shows that the maximum recurrence was observed in the gradation of 0-5 cm in the third decade of October, in the first, second and third decades of November, the first decade of December and in the first and second decades of April. It is 100%. The maximum height was in the gradation of 31-50 cm and was fixed from the first decade of January to the second decade of February and in almost all these decades was equal to 4%.

A comparative analysis of the two periods shows that the appearance of snow cover at the Svitlovodsk station coincides and is observed in the third decade of October. The disappearance of snow cover is different - according to climatic norms it was recorded in the second decade of April, and for the period 1996-2018 it was observed in the third decade of April. Maximum recurrences of 100% were observed in the gradation of 0-5 cm in both periods, but can be observed in different decades. The maximum height is defined in the gradation of 31-50 cm, but is fixed in different decades for certain periods.

in the first decade of January - 28%. The maximum recurrence in the gradation 11-20 cm - 27% of cases was in the first decade of February. The highest recurrence - 26% in the gradation of 21-30 cm was observed in the third decade of January. It is possible to note that in a gradation of 31-50 cm the maximum of recurrence was 12% in the first and second decades of March.

The appearance of snow cover occurred in both periods in the third decade of October (Table 7, Table 8), and the decline was observed according to climatic norms a decade earlier than in the period 1996-2018, in the second decade of April. The maximum recurrence in the period 1961-1990 was also observed in the gradation of 0-5 cm, but in the third decade of October, in the first decade of November, in the first and second decades of April and was 100%. The greatest height was observed in the gradation of 31-50 cm, recorded from the third decade of December to the second decade of March and ranged from 3 to 18% in contrast to the first period, when such heights were detected in the first two decades of February and March with recurrence values from 8 up to 12%.

At Znamyanka station, the highest recurrence values were observed in the gradation of 0-5 cm in

Table 7. Recurrence of the decadal height of snow cover by decades at the station Novomyrhorod for the period 1996-2018 (%)

Gradation	X	XI			XII			I			II			III			IV		
	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0-5	100	100	84	77	78	77	66	39	55	39	27	53	45	52	56	82	100	100	100
6-10			8	8	11	6	10	28	15	9	22	9	20	6	13	6			
11-20			8	15	11	17	24	22	20	26	27	13	15	24	19	6			
21-30								11	10	26	14	17	20	6		6			
31-50											10	8		12	12				

For Novomyrhorod station, the highest values of recurrence were observed in the gradation of 0-5 cm in the third decade of October, in the first decade of November and from the first to the third decades of April. They are 100% (Table 7). In the gradation of 6-10 cm, the maximum recurrence was recorded

the third decade of October, in the first decade of November and from the first to the third decade of April and are 100% (Table 9). In the gradation of 6-10 cm, the maximum recurrence was recorded in the first decade of January - 42%. The maximum recurrence for the gradation of 11-20 cm - 38% of cases was in

Table 8. Recurrence of the decadal height of snow cover by decades at the station Novomyrhorod for the period 1961-1990 (%)

Gradation	X	XI			XII			I			II			III			IV	
	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
0-5	100	100	74	83	71	50	53	48	52	33	53	36	27	27	55	79	100	100
6-10			13	17	19	46	32	28	28	29	7	25	23	27	15	5		
11-20			13		10		7	16	3	19	25	21	30	28	15	5		
21-30						4	4	4	14	15	11	7	8		5	11		
31-50							4	4	3	4	4	11	12	18	10			

the first decade of February . The highest recurrence - 12% in the gradation of 21-30 cm was observed in the first decade of March. The maximum recurrence of the gradation of 31-50 cm ,12% , was also in the first decade of March. It should be noted that at this station, in contrast to the previous two, the maximum height of snow cover was in the gradation of 51-75 cm in the second decade of March, the frequency of which was 7 %.

the gradation of 0-5 cm was observed only in the third decade of October and in the second decade of April and was 100% (Table 10).

Analysis of the frequency of decadal height at Kropyvnytskyi station shows that the highest values of recurrence were observed in the gradation of 0-5 cm in the third decade of October and in the first decade of November and from the first to the third decades of April. They are 100% (Table 11). In the gradation of 6-10 cm, the maximum recurrence was recorded in the first decade of January - 38%. The maximum recurrence in the gradation 11-20 cm , 34% of cases , was in the third decade of January . The highest recurrence in the gradation of 21-30 cm , 10% ,was observed in the second decade of February. In the gradation 31-50 cm, the maximum was fixed in the second decade of February, where the recurrence was 8%. The appearance of snow cover was recorded

Table 9. Recurrence of the decadal height of snow cover by decades at Znamyanka station for the period 1996-2018 (%)

Gradation	X	XI			XII			I			II			III			IV		
	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0-5	100	100	80	66	75	75	72	48	55	42	28	54	61	59	46	79	100	100	100
6-10			20	17	19	13	13	42	15	19	19	14	16	6	27	14			
11-20				17	6	12	10	10	25	24	38	23	12	11	13				
21-30							5		5	10	5		6	12					
31-50										5	10	9	5	12	7	7			
51-75															7				

In the period 1961-1990, similar maximum heights were also recorded, but from the second decade of February to the second decade of March. The recurrence ranged from 4-9% (Table 10). The appearance of snow cover was recorded in the third decade of October in both periods. The disappearance was observed in the second decade of April in the period 1961-1990, which is one decade earlier than in the period 1996-2018. The maximum recurrence in

Table 10. Recurrence of the decadal height of snow cover by decades at the Znamyanka station for the period 1961-1990 (%)

Gradation	X	XI			XII			I			II			III			IV	
	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
0-5	100	86	80	85	76	43	60	44	43	32	36	39	31	39	69	63	66	100
6-10		14	20	10	14	38	29	36	25	25	25	25	23	19	9	16	17	
11-20				5	10	19	7	16	21	32	25	21	23	30	9	16	17	
21-30							4	4	7	7	7	7	19	4	4			
31-50									4	4	7	4		4		5		
51-75												4	4	4	9			

in the third decade of October, the disappearance was observed in the third decade of April at the station for both periods (Table 11, Table 12).

Maximum recurrences were observed in the gradation of 0-5 cm in the third decade of October, in the first decade of November, from the first to the third decade of April and were 100% for these periods. It should be noted that the maximum height was recorded in the gradation of 51-75 cm, and was fixed only in the third decade of February and was equal to 4% only according to climatic norms.

Table 11. Recurrence of the decadal height of snow cover by decades at Kropyvnytskyi station for the period 1996-2018 (%)

Gradation	X	XI			XII			I			II			III			IV		
	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0-5	100	100	92	64	83	77	72	52	50	49	45	65	71	59	69	82	100	100	100
6-10				9	11	17	18	38	22	9	31	13	10	12	13	6			
11-20			8	27	6	6	10	10	18	34	10	10	14	23	6	12			
21-30									10	8	9	4	5		6				
31-50											5	8		6	6				

At Gaivoron station, the analysis of the time distribution of the recurrence of the decadal height of snow cover shows that the largest values of this indicator were observed in the gradation of 0-5 cm in the first decade of November and from the first to the second decade of April. They were 100% (Table 13). In the gradation of 6-10 cm, the maximum recurrence was recorded in the second decade of December - 40%. The maximum recurrence in the gradation 11-20 cm - 33% of cases, was in the second decade of January . The highest recurrence in the gradation of 21-30 cm - 12% , was observed in the second decade of February. The gradation of 31-35 cm had a maximum recurrence of 9% in the third decade of January. The appearance of snow cover was recorded in the first decade of February, which is one decade later than in the period 1961-1990 (Table 13, Table 14).The disappearance was observed in the second decade of April in both periods. The maximum recurrence was observed in the gradation of 0-5 cm and was 100%, but can be observed in different decades. It can be noted that the maximum height was recorded in the gradation of 31-50 cm for both periods, was fixed in different decades and ranged from 4 to 9%.

Table 12. Recurrence of the decade height of snow cover by decades at Kropyvnytskyi station for the period 1961-1990 (%)

Gradation	X	XI			XII			I			II			III			IV		
	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0-5	100	100	89	94	66	61	59	52	54	39	40	35	33	35	57	76	100	100	100
6-10			11		17	27	19	20	21	25	14	29	29	17	5	6			
11-20				6	11	8	15	20	11	25	28	14	8	17	14	12			
21-30					6	4	7	8	7	4	11	11	13	9	10	6			
31-50									7	7	7	11	13	22	14				
51-75													4						

Analysis of the frequency of decadal height for the period 1996-2018 at Pomichna station shows that the highest values were observed in the gradation of

Table 13. Recurrence of the decadal height of snow cover by decades at Gaivoron station for the period 1996-2018 (%)

Gradation	XI			XII			I			II			III			IV	
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
0-5	100	86	75	84	53	65	47	22	48	50	41	45	79	75	93	100	100
6-10			17	8	40	23	37	39	17	27	12	33		25	7		
11-20		14	8	8		12	11	33	22	14	30	22	14				
21-30					7		5	6	4	9	12		7				
31-50									9		5						

Table 14. Recurrence of the decadal height of snow cover by decades at Gaivoron station for the period 1961-1990 (%)

Gradation	X	XI			XII			I			II			III			IV	
	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
0-5	100	100	87	93	81	80	69	52	52	48	50	61	44	37	66	69	75	80
6-10				7	6	12	15	20	12	11	8	7	20	35	14	23	25	20
11-20			13		13	8	12	16	12	30	27	11	4	5	10	8		
21-30							4	12	20	11	15	14	28	18	10			
31-50									4			7	4	5				

0-5 cm in the third decade of October, in the first and second decades of November and from the first to the third decade of April. They were 100% (Table 15). In the gradation of 6-10 cm, the maximum recurrence was recorded in the first decade of January – 30%. The maximum recurrence in the gradation of 11-20 cm – 33% of cases, came in the third decade of January. The highest recurrence – 12%, in the gradation of 21-30 cm was observed in the first decade of March. The gradation of 31-50 cm was recorded only in the second decade of January and in the first decade of February with a recurrence of 5%. The appearance of snow cover was recorded in the third decade of October in both periods (Table 15, Table 16). The disappearance was observed in the third decade of April in the period 1996-2018, which is one decade later than according to the climate cadastre. The maximum recurrence was observed in the gradation of 0-5 cm and was 100%, but it can be observed in different decades. The maximum height was recorded in the gradation of 21-30 cm from the second decade of January to the second decade of March in the period 1961-1990. This characteristic for the later period was in the gradation of 31-50 cm.

For Dolynska station, the highest values of recurrence were observed in the gradation of 0-5 cm in the first and second decades of November and in the first decade of April. They were 100% (Table 17). In the gradation of 6-10 cm, the maximum recurrence was recorded in the first decade of January - 30%. The maximum recurrence of the gradation of 11-20 cm - 23% of cases, was in the third decade of January . The highest recurrence - 9% , in the gradation of 21-30 cm was observed in the third decade of January and in the first decade of February. The gradation of 31-50 cm was fixed only in the first and second decades of February.

The appearance of snow cover was recorded in the first decade of November, which occurred a month later than according to climatic norms (Table 18). The disappearance was observed in the first decade of April, two decades earlier than in the period 1961-

Table 15. Recurrence of the decadal height of snow cover by decades at the Pomichna station for the period 1996-2018 (%)

Gradation	X	XI			XII			I			II			III			IV		
	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0-5	100	100	100	84	92	82	69	60	58	43	41	59	60	59	58	79	100	100	100
6-10				8	8	12	26	30	22	14	23	14	15	12	17	14			
11-20				8		6	5	10	10	33	22	18	20	17	25	7			
21-30									5	10	9	9	5	12					
31-50									5		5								

Table 16. Recurrence of the decadal height of snow cover by decades at the Pomichna station for the period 1961-1990 (%)

Gradation	X	XI			XII			I			II			III			IV	
	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
0-5	100	100	86	100	95	81	78	71	57	55	57	57	48	48	69	82	100	100
6-10			14		5	19	15	22	18	19	21	18	20	34	5	18		
11-20							7	7	21	22	18	18	28	9	21			
21-30									4	4	4	7	4	9	5			

Table 17. Recurrence of the decadal height of snow cover by decades at Dolynska station for the period 1996-2018 (%)

Gradation	XI			XII			I			II			III			IV
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1
0-5	100	100	80	82	93	94	60	60	45	48	69	72	75	65	80	100
6-10			20	18			30	20	23	17	5	6		14	20	
11-20					7	6	10	20	23	22	16	22	19	21		
21-30									9	9	5		6			
31-50										4	5					

1990. The maximum recurrence is observed in the gradation of 0-5 cm and is 100%, but was observed in different decades. The maximum height was recorded in the gradation of 51-75 cm, recorded in the third decade of February with a recurrence of 5% only according to climatic norms.

Table 18. Recurrence of the decadal height of snow cover by decades at Dolynska station for the period 1961-1990 (%)

Gra-dation	X			XI			XII			I			II			III			IV		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0-5	100		100	100	100	83	80	81	76	70	57	50	48	48	32	48	63	84	100	100	100
6-10						17	20	14	19	20	30	27	30	26	26	19	6	8			
11-20								5	5	10	9	14	9	13	32	28	25	8			
21-30											4	9	13	9	5						
31-50														4		5	6				
51-75															5						

At the station Bobrynets the largest values of recurrence were observed in the gradation of 0-5 cm in the first and second decades of November and in the first decade of April. They were 100% (Table 19). In the gradation of 6-10 cm, the maximum recurrence was recorded in the third decade of November - 25%. The maximum recurrence in the gradation of 11-20 cm - 30% of cases, was in the second decade of March. The highest recurrence - 25%, in the gradation of 21-30 cm was observed in the first decade of March.

Table 19. Recurrence of the decadal height of snow cover by decades at Bobrynets station for the period 1996-2018 (%)

Gradation	XI			XII			I			II			III			IV
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1
0-5	100	100	75	91	93	83	69	66	41	48	68	69	50	60	88	100
6-10			25	9	7	17	13	6	11	19	6	6	8	10	12	
11-20							12	22	27	19	10	6	17	30		
21-30							6	6	21	5	5	19	25			
31-50										9	11					

Table 20. Recurrence of the decadal height of snow cover by decades at Bobrynets station for the period 1961-1990 (%)

Gradation	X	XI			XII			I			II			III			IV	
	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
0-5	100	100	83	87	83	79	84	61	47	55	47	49	45	47	64	92	100	50
6-10			17	13	17	21	8	35	45	26	35	8	17	14	18	8		50
11-20							8	4	4	15	14	31	17	29	12			
21-30												8	13	5	6			
31-50									4	4	4	4	8	5				

The gradation of 31-50 cm was fixed in the first and second decades of February. The appearance of snow cover was recorded in the first decade of November, in contrast to the climatic norm, where the appearance of snow was observed in the third decade of October (Table 20). The disappearance was observed in the first decade of April, which occurred one decade earlier than in the period 1961-1990. The maximum frequency was observed in the gradation of 0-5 cm and is 100%, can be observed in different decades. The maximum height was recorded in the gradation of 31-50 cm, was fixed in different decades and ranged from 4 to 11% in different periods.

Conclusions.

Analysis of snow cover in Kirovohrad region makes it possible to say that at the beginning of the XXI century there were changes in the formation of snow cover. In the last few decades in the west and south of the region, snow cover has formed a decade later than according to climatic norms. Disappearance of snow was determined in the third decade of April in the north of the region, in contrast to the period of the second half of the twentieth century, when disappearance of snow was observed almost throughout the region in the second decade of April. At Kropyvnytskyi station, located in the central part of the Kirovohrad region, the appearance and disappearance of snow cover are determined within the same limits for the two periods. The height of snow at the beginning of the XXI century decreased both in terms of averages and extremes. The frequency of winters with the highest decadal height of snow cover in different gradations varies greatly in the study periods. For 1996-2018, the maximum was observed in the gradation of 1-5 cm, significant recurrence was found for a height of 0 cm; in the climatic norm the greatest recurrence was recorded in the gradation of 11-20 cm, significant indicators were observed in the gradation of 21-30 cm of snow cover. The maximum recurrences of the decadal height of the snow cover are 100%. They are defined in the gradation of 0-5 cm in both periods at the beginning and end of the period with snow cover.

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Comparative characteristics of the petrographic composition and quality of coal series C_1^2 and C_1^3 of the Prydniporovia Block

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Abstract. Taking into consideration the whole history of geological development of the Western Donbas, data on composition and grade of C_1^2 series coal involved information about the geotectonic development of the Basin. To satisfy the objectives, a system of research methods, covering petrographic, computational, statistical, chronological, comparative and other methods, has been applied. In the process of identification of the petrographic composition and grade of series C_1^2 coal on the territory of the Prydniprovia Block, and determination of lateral regularities of their change as well as change in stratigraphic section of the Lower Carboniferous, data of petrographic as well as chemical and technological indices of the coal seam c_1 were generalized along with data of all seams of C_1^3 series. The activities helped define genetic features of series C_1^2 coal as well as stratigraphic and lateral regularities of changes in the coal composition. The differences in the petrographic composition as well as in the chemical and technological characteristics of series C_1^2 and C_1^3 are indicative of dissimilar conditions of formation of their peat depositions. It has been determined that compared with C_1^3 series coal, the coal of C_1^2 series contains more humidity and fewer mineral impurities. It is characterized by higher values of sulfur content, volatile-matter content, and combustion heat. The ultimate composition of coal seams of C_1^2 series is characterized by smaller values of carbon and oxygen contents as well as greater hydrogen content. The conclusions on common features and differences in the petrographic composition as well as chemical and technological features of coal seams of C_1^2 and C_1^3 series, and regularities of their changes over the area of the seam occurrence was assessed.

Keywords: coal seam, vitrinite, liptinite, inertinite, petrographic composition

Порівняльна характеристика речовинно-петрографічного складу і якості вугілля світ C_1^2 та C_1^3 Придніпровської брили

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Анотація. Враховуючи історію геологічного розвитку Західного Донбасу у цілому, узагальнення матеріалів зі складу та якості вугілля світи C_1^2 виконано з урахуванням геотектонічного розвитку басейну. Для виконання поставлених задач використано комплекс методів досліджень, що включає петрографічний, розрахунковий, статистичний, хронологічний, порівняльний, тощо. При визначенні типового петрографічного складу та якості вугілля світи C_1^2 на площі Придніпровської брили і встановленні латеральних закономірностей їх зміни, та зміни у стратиграфічному розрізі нижнього карбону були додатково узагальнені дані петрографічних та хіміко-технологічних показників вугільного пласта c_1, та узагальнені данні для усіх пластів світи C_1^3. Це дозволило визначити генетичні особливості вугілля світи C_1^2 та встановити стратиграфічні і латеральні закономірності зміни складу вугілля. Виявлена різниця, як у петрографічному складі, так у хіміко-технологічних показниках вугільних пластів світ C_1^2 и C_1^3 вказує на різні умови формування їх торфовищ. Встановлено, що вугілля світи C_1^2 у порівняні з вугіллям світи C_1^3 вміщує більше вологи та менше мінеральних домішок. Для них характерні більш високі значення сірчистості, виходу летких, теплоти згоряння. Елементний склад вугільних пластів світи C_1^2 характеризується меншими значеннями вмісту вуглецю та кисню та більшою кількістю вмісту водню. Оцінено спільність та відмінність у петрографічному складі та хіміко-технологічних властивостях вугільних пластів світ C_1^2 та C_1^3 і закономірностях їх зміни по площі поширення пластів та у стратиграфічному розрізі.

Ключові слова: вугільний пласт, вітриніт, ліптиніт, інертиніт, петрографічний склад

Introduction.

Expansion of coal seams over the whole multi-kilometer mass of the field, starting from the top of the Visean layers up to the Upper Carboniferous, is the feature of coal formation of the Donetsk Basin (Radziwill, 2012). Coal of C_2^3-C_2^7 series of the Middle Carboniferous has been studied in the most thorough manner. In terms of the Lower Carboniferous, the basic commercial seams are observed in C_1^3 series. Due to their poor carbon bearing degree, the "subcoal" series of the Visean age (C_1^2) belong to the least understood Donbas series. Petrographic as well as chemical and technological characteristics of coal seams of the Mezhova series were studied according to the certain wells while researching the basic carbon Samara series (C_1^3). The lithological and facial characteristics of C_1^2 series have been analyzed more thoroughly. It has been proved (Radziwill, 2012) that it is an independent rock complex differing greatly from carbon rocks of the underlying series (C_1^1), and from the overlying carbon mass (C_1^3). Further, three smaller subformations have been separated within the Low Carboniferous formation. The subformations are characterized by structural features as well as sediment and peat accumulation. Poorly carbonized bottom swampy-marine transgressive subformation underlies the carbon formation (Radziwill, 2012).

Early information concerning petrology and coal grade of C_1^2 series was obtained for single wells in Pavlohrad District. During detailed exploration in the late 1950s within *Kosminni* and *Mezhivski* sites, b_6 and b_8 coal seams were prospected and analyzed. During the following years, geological prospecting activities helped to identify seams of C_1^2 series in Petrykivka District, and Novomoskovsk District as well as in the territory of the Southern Donbas.

In large, the exploration degree of the petrographic composition and coal grade of C_1^2 series may be evaluated according to the generalized scientific sources (Ivanova, 2018, 2018a, 2014; Savchuk, 2006, 2013, 2014a, b, 2017; Shulha, 2010). Specifically, The Atlas of the Lower Carboniferous of the Donets Basin contains no information concerning the problem. In more detail, the chemical and technological as well as petrographic characteristics of the series coal were considered by S.V. Savchuk, who published his paper in 1963 under the supervision of O.Z. Shyrokov. Coal seams of C_1^2 series were characterized only for the Pavlohrad-Petropavlivka coal area. Information concerning composition of series C_1^2 coal seams and their grade, obtained in the process of geological prospecting activities in Novomoskovsk District, Petrykivka District, and the territory of the Southern Donbas, was generalized together with series C_1^3 seams (Ivanova, 2018, 2014; Shulha, 2010). Therefore, it turned out that comparison of features of petrographic and technological characteristics of series C_1^2 coal seams and coal seams of C_1^3 series is not sufficient. Up to now, information on the petrographic as well as chemical and technological characteristics of series C_1^2 coal seams, obtained within the considerable area from Petrykivka deposit in the west to the Southern Donbas in the east has been covered by a negligible quantity of papers (Radziwill, 2012; Savchuk, 2017). At the same time, the first coal seams, formed at the very beginning of the pulsing development of the Donets Depression and which originated the initial commercial coal reserves in Ukraine, are associated with the C_1^2 series. That is why the information is of practical and theoretical value.

The objective of the article was to identify the features of the petrographic composition and quality of coal seams of series C_1^2 and to establish rules of their change in the area of distribution of coal seams. Taking into consideration the whole history of geological development of the Western Donbas, data on composition and grade of C_1^2 series coal involved information about the geotectonic development of the Basin. The territory can be considered as a system of large tectonic blocks, among which the Samara Block, occupying a central share of the Western Donbas, is their hugest part. The Kalmius Block is east of the Samara Block; the Prydniprovia Block is west of it (Radziwill, 2012).

Materials and methods of investigation.

To satisfy the objectives, a system of research methods, covering petrographic, computational, statistical, chronological, comparative and other methods, has been applied. In the process of identification of the petrographic composition and grade of series C_1^2 coal in the territory of the Prydniprovia Block, and determination of lateral regularities of their change as well as change in the stratigraphic section of the Lower Carboniferous, data of petrographic as well as chemical and technological indices of a coal seam c_1 were generalized along with data of all seams of C_1^3 series. The activities helped define genetic features of series C_1^2 coal as well as stratigraphic and lateral regularities of changes in the coal composition.

Results.

The Prydniprovia Block is a site of the southern boundary of the Dnieper-Donets Depression. It has been proved that Precambrian rocks of the Prydniprovia Block rise slightly over the Samara Block. The

Vorskla fault borders the Block northwestwards; the Mykhailivka fault and Karabynivka fault border it to the north east. In the context of the Prydniprovia Block, measures of C_1^2 series occur within the area of the Petrykivka deposit and Novomoskovsk deposit. They occur transgressively right on the rocks of crystalline basement. Average thickness of the series is minor being 127 m and 167 m respectively. In terms of the whole 2.3-4.3 m thickness of the coal seams and layers, the total carbonous coefficient is 1.9-2.5.

The series deposits are represented by limestones alternating with argillites, aleurites, sandstones, and coal. Marine deposits are the characteristic feature of facial composition of the series.

Generally, seams of the series are characterized by a noncommercial thickness being 0.05 to 0.50 m. Within the bottom share of the series (B_4-B_9) the number of coal layers is 11. They are not common within the area characterized by the unstable thickness not exceeding 0.45 m. For the most part, the top share of the series (B_9-C_1) is represented by aleurites. Such seams as b_3^3, b_4, b_5, b_7, b_8, and b_9 are characterized by a noncommercial thickness exclusive of b_6 and b_7 seams.

Within the Petrykivka deposit, b_6 seam with more than 0.45 m thickness prevails southwest of sites №1-2 and №3-4.

Exteriorly, coal of b_6 seam is greyish-black with a brownish shade in places; it is of mean density being sometimes viscous. Its jointing is either tabular or thinly laminated; fracture is uneven angular one.

Mineral impurities are in the form of fine grains as well as in the form of individual inclusions. They are represented by pyrite, calcite, and kaolinite. Pyrite is the commonest, being available in the form of concretions, layers, and small inclusions. Calcite is presented in the form of gouges in endogenic fractures. Kaolinite, filling usually vitrite fractures, occurs relatively often.

Macerals of the vitrinite group are widespread in the petrographic composition of $в_6$ seam. In the context of certain wells, their share varies from 49.0 to 75.0% being 65.1% on average. Macerals of liptinite follow them in abundance (Table 1). Compared with the liptinite group, macerals of inertinite group occur to a lesser degree, being 16.5% on the average. It should be noted that in terms of certain layer intersections, the composition of all the maceral groups varies over a wide and approximately equal value range being 26, 20, and 22% respectively. In some wells, layers of sapropelic-humus coal, represented mainly by boghead-cannel, occur in addition to humus coal.

Coal of the layer intersections belongs to the two petrographic types – durain-clarain and clarain-durain. In terms of typical petrographic composition, coal of the seam belongs usually to a spore durain-clarain subtype (Table 1).

Petrographic composition of $в_7$ and $в_8$ coal seams within Petrykivka deposit is almost identical to the composition of b_6 seam (Table 1). An almost similar amount of vitrinite, liptinite, and inertinite is indicated. In terms of certain layer intersections, changes in the content of the vitrinite maceral group take place within the same b_6 seam intervals. Petrographic subtype of such coal seams as b_7 and b_8 is a durain-clarain spore one.

In total, coal of C_1^2 seam of Petrykivka deposit belongs to a durain-clarain type. Spore coal subtype is the most widespread one (Table 1). Nonavailability of the seams consisting of durain coal type should be noted.

Macerals of the vitrinite group are the commonest ones within the organic group of c_1 seam coal (C_1^3 series). In the context of certain layer intersections, their number varies from 43.0 to 71.0%. On average, it is 60.0% in terms of the seam being less compared with C_1^2 series seams (Table 1).

Macerals of the liptinite group follow them; their mean is 22.0%. Compared with the liptinite group, the number of inertinite group macerals is lower , being 18.0% on the average. In comparison with C_1^2 series seams, petrographic composition of c_1 seam is more variable being characterized by the lower amount of the vitrinite group, and larger amount of macerals of inertinite and liptinite groups (Table 1).

As for the layer intersections, coal of c_1 seam belongs predominantly to the clarain-durain group (81.7%). Occurrence of the layer intersections, the coal of which belongs to a durain type (12.2%), should be mentioned. Durain-clarain varieties are 6.1% only (Table 1).

As for the spread area of c_1 seam, clarain-durain with 65-50% vitrinite content prevails. Mixed clarain-durain types occur along the southern extension of the sites; spore types are present along the northern one. Clarain-durain with 50% down to 40% of vitrinite content, and durain-clarain with 80% down to 65% of vitrinite content forms small areas. On the whole, coal of c_1 seam of Petrykivka deposit belongs to a clarain-durain spore type.

Table 1 demonstrates the typical petrographic composition of each commercial seam of C_1^3 series within the Petrykivka deposit (exclusive of c_1 seam).

In the context of certain seams, content of macerals of the vitrinite group varies from 49 to 65%; its average value is 54.2%. Inertinite content is 19 to 26%; and liptinite is 16 to 26%. In terms of the average seam values, the quantity of maceral groups varies within the fewer ranges (Table 1).

From the viewpoint of its material composition, the Lower Carboniferous coal of C_1^3 series of the Petrykivka deposit belongs to a clarain-durain type. Sometimes, it belongs to a durain or to a durain-clarain type.

The data helps conclude that according to its petrographic composition, C_1^2 series coal of the Petrykivka deposit differs from C_1^3 series coal. In their total petrographic composition, they contain more macerals of the vitrinite group, and fewer macerals of the inertinite and liptinite groups. On the whole, C_1^2 series coal belongs to a spore durain-clarain type and C_1^3 series coal belongs to a spore clarain-durain type. Stratigraphic section from bottom seams to the top ones explains that typical petrographic composition has a tendency to decreased vitrinite quantity. In turn, the maceral content of the inertinite and liptinite groups increases. As for the petrographic composition, seam c_1 coal is found in between C_1^2 series seams and other seams of C_1^3 series (Table 1).

Among the coal seams of C_1^2 series, $в_7$ seam is the most widespread, occurring mainly in the field of *Novomoskovska #4* mine within the area of Novomoskovsk deposit. The seam is of variable thickness (0.1 m to 1.40 m). 0.75-0.90 m thickness prevails; its mean thickness is 0.73 m. The central share of the site demonstrates more than 0.8 m thickness of the seam. It is represented by small separated areas within the remaining territory.

Hence, according to the mining conditions, reserves of $в_7$ seam have been referred to the noncommercial ones.

The seam is of complex structure. Layers of carbonic argillites are 0.05-0.20 m, and 0.30-040 m more rarely. Argillite occurs within the seam roof; aleurite occurs less frequently. Its depth varies from 250 to 750 m being 415 m on average.

Predominantly, the coal is of a humic type. Sometimes, sapropelic-humic layers occur. Microscopically, the coal is semi-dull and semi-lustrous striated densely with rare vitrain bands.

The coal is a complex mixture of vitrain-inertinite-liptinite maceral groups.

The vitrain group is the basis of the petrographic composition. The amount of the mineral varies from 46.0% up to 81.0%, being 68.0% on average. The liptinite group, the mean of which is 17.0%, follows vitrain in maceral content within the total organic coal mass. In terms of the certain wells, its amount varies from 5.0 to 26.0%. The inertinite group is the least occurred one. Its average content is 15.0 %, somewhat less than the liptinite group content (Table 1). In terms of the certain wells, its amount varies from 9.0% to 36.0%.

From the viewpoint of its material composition, the coal belongs to the durain-clarain (60%) and clarain - durain (40%) types. Nonavailability of a durain coal type should be mentioned. The spore coal subgroup is the most widespread among the petrographic subtypes (Table 1). As for the area, spore durain-clarain type is the typical petrographic composition.

In the context of the petrographic composition of c_1 seam, occurring within the area of the mine *Novomoskovska #4*, the average amount of the maceral vitrain group is 63.0% (55-74%). The quantity of macerals of inertinite and liptinite groups is almost identical, being 18.0% and 19.0% respectively (Table 1).

In terms of the typical material composition of c_1 seam, durain-clarain type prevails (76%). The number of durain-clarain type samples is 22%. The number of layer intersections consisting of a durain coal type is low, being 2% on average (Table 1). The shares of the spore coal subtypes and the mixed one are represented almost identically. In the context of the deposit, the petrographic subtype of the coal seam is of clarain-durain spore type.

In terms of petrographic composition of C_1^3 series (c_o-c_6), the other coal seams of the mine *Novomoskovska #4* also differ from petrographic composition of b_7 seam (C_1^2 series).

Hence, stratigraphic section of the Novomoskovsk deposit shows that a gradual decrease in the vitrain maceral group takes place from b_7 seam to c_6 seam as well as the increase in inertinite and liptinite macerals (Table 1). Coal of C_1^2 series belongs to a durain-clarain type and coal of C_1^3 series belongs to a clarain-durain type.

The data concerning the difference in petrographic compositions of seams of C_1^2 and C_1^3 series are indicative of dissimilar conditions of the formation of peat depositions. The information is also supported by the data on the composition and grade of the series coal.

Table 2 explains chemical and technological characteristics of the coal seams of C_1^2 and C_1^3 series.

C_1^2 series coal is characterized by high humidity. In the context of the Prydniprovia Block, it is 9.9 % on average. Predominantly, the coal is of mid-ash type (Table 2). On the territory of the Prydniprovia Block, ash content of coal patches of C_1^2 series varies from 7.0 to 21.0%. It is 12.8% for the Petrykivka deposit and 11.8% for the Novomoskovsk deposit. Its high content has been identified within the areas of seam thinning. In terms of ash, concentratibility is medium and heavy. The ash is of a ferrous type. It has high content of Fe_2O_3 (24.4-29.9 %) and CaO (8.3 – 8.7 %), and low content of SiO_2 and Al_2O_3. High content of Na and K oxides (8.5-10.3%) as well as Mg (3.0-

Table 1 - Petrographic composition, types, and subtypes of coal seams of C_1^2 and C_1^3 series of Prydniprovia Block in the Western Donbas

Deposit, district, site	Series	Seam	Petrographic composition, %			Petrographic type of coal, %			Petrographic subtype of coal, %		Petrographic subtype of seams
			Vt	I	L	durain-clarain	clarain - durain	durain	mixed	spore one	
Petrykivka deposit	C_1^2	b_6	49.0-75.0 65.1	9.0-29.0 16.5	13.0-35.0 18.4	55.0	45.0	0	24.0	76.0	durain-clarain spore
		b_7+b_8	49.0-76.0 65.2	14.0-23.0 17.0	7.0-25.0 17.8	75.0	25.0	0	40.0	60.0	durain - clarain spore
		$b_6+b_7+b_8$	49.0-76.0 65.1	9.0-29.0 16.8	7.0-35.0 18.1	65.0	35.0	0	31.3	68.7	durain - clarain spore
	C_1^3	c_1	43.0-71.0 60.0	5.0-34.0 18.0	13.0-32.0 22.0	6.1	81.7	12.2	52.5	47.0	clarain - durain spore
	C_1^3	$c_2^1-c_{10}$	49.0-65.0 54.2	19.0-26.0 22.0	16.0-26.0 23.8						clarain - durain spore
Novomoskovsk deposit, Field of mine #4	C_1^2	b_7	46.0-81.0 68.0	9.0-36.0 15.0	5.0-26.0 17.0	60.0	40.0	0	38.0	62.0	durain - clarain spore
	C_1^3	c_1	55.0-74.0 63.0	11.0-27.0 18.0	12.0-25.0 19.0	22.0	76.0	2.0	47.0	53.0	clarain - durain spore
	C_1^3	c_0-c_6	56.0-71.0 58.6	11.0-22.0 19.5	16.0-24.0 21.9						clarain - durain spore
Prydniprovia Block	C_1^2	$b_6+b_7+b_8$	46.0-81.0 66.5	9.0-36.0 15.9	5.0-35.0 17.6	58.0	42.0	0	37.0	63.0	durain - clarain spore
	C_1^3	c_1	46.0-81.0 61.5	9.0-29.0 18.0	7.0-35.0 20.5	14.0	79.0	7.0	47.0	53.0	clarain - durain spore
	C_1^3	c_1-c_{17}	46.0-81.0 58.1	9.0-29.0 20.0	7.0-35.0 21.9						clarain - durain spore

Table 2 -Characteristics of the chemical composition and grade of coal seams of C_1^2 and C_1^3 series (Prydniprovia block of the Western Donbas)

Deposit, district	Series	Seam	Technical analysis, from-to/average					Ultimate composition, %	
			W^a, %	A^d, %	S_t^d, %	V^{daf}, %	Q_s^{daf} MJ/кг	C^{daf}	H^{daf}
Petrykivka	C_1^2	b_6	3.7-12.4 8.7	8.0-20.0 14.8	1.98-8.28 4.02	42.0-48.0 45.1	27.5-28.9 28.1	68.0-74.0 70.3	5.4-5.8 5.56
		b_7+ b_8	4.1-13.6 9.1	7.0-21.0 11.0	1.99-7.24 2.96	41.0-45.0 44.9	28.9-29.7 29.3	71.0-72.0 71.5	4.8-5.4 5.20
		b_6+ b_7+ b_8	3.7-12.4 8.9	7.0-21.0 12.8	1.98-8.28 3.49	41.0-48.0 45.0	27.5- 29.7 28.7	68.0-74.0 70.9	4.8-5.8 5.46
	C_1^3	c_1	1.5-18.7 8.8	4.0-32.0 13.9	0.41-7.52 1.87	39.0-49.0 44.6	27.6-30.0 28.3	72.0-74.0 72.6	4.7-6.0 5.37
	C_1^3	c_1-c_{10}	9.8	14.3	1.56	44.7	29.8	73.6	5.19
Novomoskovsk	C_1^2	b_7	9.0-13.0 11.0	7.0-19.0 11.8	1.48-10.74 4.97	44.0-49.0 47.0	27.6 - 30.5 29.4	70.0-74.0 72.4	4.7-5.8 5.44
	C_1^3	c_1	6.6-17.0 9.9	7.0-24.0 12.7	0.52-14.07 3.47	43.0-48.0 46.0	28.8 - 30.3 29.5	71.0-75.0 72.8	4.5-5.68 5.16
Prydniprovia block	C_1^2	b_6+ b_7+ b_8	3.7-13.0 9.9	7.0-21.0 12.3	1.48-10.74 4.23	41.0-49.0 45.9	27.5 - 30.5 29.1	68.0-74.0 71.6	4.7-5.8 5.45
	C_1^3	c_1	1.5-18.7 9.4	4.0-32.0 13.7	0.40-14.07 2.67	39.0-48.0 43.4	27.6 - 30.5 28.7	71.0-75.0 72.7	4.5-6.0 5.27

3.44 %) is a specific feature of chemical ash composition of the area. The coal is of sulfide and multisulfide type. Sulfur amount of certain samples varies broadly from 1.99 to 10.77%; 3.49% is its average value for the Petrykivka deposit, and 4.97% for the Novomoskovsk deposit. Average sulfur content in the coal of C_1^2 series of the Prydniprovia Block is 4.23% (Table 2). Phosphorous amount in the coal is increased. Within the area of Petrykivka District, volatile-matter content (V^{daf}, %) varies from 41.0% to 48.% , being 45.0% on average. As for the area of Novomoskovsk District, its values are greater, being 44.0% to 49.0% (47.0% on the average). In terms of C_1^2 series on the territory of the Prydniprovia Block, average value of the index is 45.9% (Table 2). Combustion heat per the fuel mass is almost 28.7 MJ/kg for Petrykivka deposit coal, and 29.4 MJ/kg for the coal of the Novomoskovsk deposit. High coal humidity decreases combustion heat in terms of a dry ashless fuel (O_i^r). Its values are 20.3-20.5 MJ/kg only, which is typical for lignite. Carbon content (C^{daf}, %) is from 68.0% to 74.0 % (70.9% on the average) for Petrykivka District, and 72.4% for Novomoskovsk District. Hydrogen amount is almost similar (5.46% and 5.44 % respectively).

C_1^2 series coal does not experience coking. Only for certain samples from Novomoskovsk deposit, does plastic layer thickness achieve 5 mm. Plastometric shrinkage varies from 32 up to 55 mm, being 45 mm on the average. Semicoke output per dry mass varies from 62.3% up to 80.1% if ash content is up to 17 %. Output of semicoking resin is high, being 9.6% up to 21.9% (13.9% on the average). The resin contains numerous paraffins and phenols, which may be used for distillation. The coal is black characterized by a uniform grade composition; it belongs to D grade.

Compared with C_1^3 series coal, the coal of C_1^2 series differs in greater average values of humidity, sulfur content, volatile-matter content, combustion heat, and a smaller number of mineral impurities. The coal differs in its ultimate composition as well. It is characterized by high hydrogen content and smaller values of carbon content (Table 2).

The data have helped draw conclusions on common features and differences in the petrographic composition as well as chemical and technological features of coal seams of C_1^2 and C_1^3 series, and regularities of their changes over the area of the seam occurrence and relying upon stratigraphic section.

Conclusions.

According to their petrographic composition, coal seams of C_1^2 series belong to the spore durain-clarain type:

1. It has been identified that in terms of the total petrographic composition, C_1^2 series coal differs from C_1^3 series coal. Lower series coal is characterized by a greater content of vitrain group and smaller amount of the inertinite and liptinite groups.
2. A similar pattern has been identified for the changes in the petrographic composition of series C_1^2 and C_1^3 occurrence. The amount of the vitrain maceral group increases in north-westerly direction, in a south-eastwardly direction; in turn, the amount of inertinite and liptinite maceral groups decreases.
3. It has been determined that compared with C_1^3 series coal, the coal of C_1^2 series contains more humidity and fewer mineral impurities. It is characterized by higher values of sulfur content, volatile-matter content, and combustion heat. Ultimate composition of coal seams of C_1^2 series is characterized by smaller values of carbon and oxygen contents as well as greater hydrogen content.
4. A similar pattern has been identified for the changes in the chemical and technological characteristics of series C_1^2 and C_1^3 occurrence. Increase in combustion heat and in carbon content as well as decrease in the amount of mineral impurities take place in a north-westerly and south-easterly direction.

The differences in the petrographic composition as well as in the chemical and technological characteristics of series C_1^2 and C_1^3 are indicative of dissimilar conditions of formation of their peat depositions. In the future, it is required to perform certain activities aimed at the determination of features of maceral composition of coal seams of C_1^2 series, analysis of their petrographic structure, and consideration of the formation conditions of their peat depositions.

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The total content of macronutrients and heavy metals in the soil on devastated lands at Kryvyi Rih Iron Mining & Metallurgical District (Ukraine)

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Abstract. The relevance of the research is due to the need to develop technologies for phytoremediation of the devastated lands in the mining and metallurgical regions of Ukraine and the world. In this regard, the creation of tree plantations adapted to the ecological conditions of such territories is considered by many experts as the most promising option for innovative technologies. However, the development of artificial woodlands requires knowledge of the pedogeochemical characteristics of devastated lands. The aim of the work was to carry out a comparative analysis of the macronutrients and heavy metals gross forms content in the soils of the devastated lands of the Kryvyi Rih mining and metallurgical region. The field studies focused on five contrasting monitoring sites of the Petrovsky dump (Central Kryvorizhzhya), which has a typical age and composition of rocks for the region. Soil sampling, drying, sieving, and sample preparation (sintering in a muffle furnace) were done in accordance with classical techniques. The concentrations of macronutrients (potassium, sodium, calcium, magnesium, sulfur, and phosphorus) and heavy metals (iron, manganese, zinc, copper, lead, and cadmium) were determined using an Inductively Coupled Plasma Mass Spectrometry (ICP-MS) X-Series 2 (Thermo Fisher Scientific, USA). The analytical part of our research was carried out on the basis of the laboratory of the Institute of Biosciences, Freiberg *University* of *Technology* and Mining Academy (Freiberg, Germany). At monitoring sites, significant differences were found in the content of macronutrients gross forms, and their variation relative to the control values as well. Potassium and sodium concentrations generally differed slightly or were close to control levels. The results of determining the content of calcium, magnesium and phosphorus indicate a significant deficiency or excess of these macronutrients in the soils of the devastated lands. An increased sulfur content was found in the soils of all monitoring sites, in some cases 4 times higher than the control level. The measured content of gross forms of iron, manganese, copper, cadmium and, partially, zinc in the soils of different monitoring sites exceeded the control values by 5.5 – 5.9 times. Thus, the analysis of the research results made it possible to establish that the soils of the devastated lands of the Petrovsky dump are characterized by unfavorable properties for the growth of most species of woody plants.

Key words: soil, devastated lands, waste rock dumps, macronutrients, heavy metals, gross forms, phytotoxicants, phyto-optimization

Валовий вміст макронутрієнтів та важких металів у ґрунтах девастованих земель Криворізького залізорудного гірничо-металургійного регіону (Україна)

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Анотація. Актуальність наших досліджень зумовлена необхідністю розробки технологій фіторемедіації девастованих земель у гірничо-металургійних регіонах України та світу. У зв'язку з цим створення деревних насаджень, адаптованих до екологічних умов таких територій, багато експертів розглядають як найбільш перспективний варіант інноваційних технологій. Однак розвиток штучних лісових масивів вимагає знання педогеохімічних характеристик девастованих земель. Метою роботи було провести порівняльний аналіз вмісту валових форм макронутрієнтів та важких металів у ґрунтах девастованих земель Криворізького гірничо-металургійного регіону. Польові дослідження були зосереджені на п'яти контрастних місцях модельного Петровського відвалу (Центральне Криворіжжя), який має типовий для регіону вік і склад гірських порід. Відбір проб ґрунту, висушування, просіювання та підготовка зразків (спікання в муфельній печі) проводили за класичними методиками. Концентрації макронутрієнтів (калію, натрію, кальцію, магнію, сірки та фосфору) та важких металів (заліза, марганцю, цинку, міді, свинцю та кадмію) визначали за допомогою мас-спектрометру з індуктивно-зв'язаною плазмою (ICP-MS) X-Серія 2 (Thermo Fisher Scientific, США). Аналітична частина нашого дослідження була виконана на базі лабораторії Інституту біологічних наук, Технологічного університету і гірничої академії Фрайберга (Фрайберг, Німеччина). На моніторингових ділянках були виявлені суттєві відмінності у вмісті валових форм макронутрієнтів та їх варіації щодо контрольних значень. Концентрація калію та натрію, як правило, незначно відрізнялася або були близькі до рівня контролю. Результати визначення вмісту кальцію, магнію та фосфору свідчать про значний дефіцит або надлишок цих макронутрієнтів у ґрунтах девастованих земель модельного відвалу. В ґрунтах усіх моніторингових ділянок було виявлено підвищений вміст сірки, в деяких випадках у 4 рази вище від контролю. Вміст валових форм заліза, марганцю, міді, кадмію та частково цинку в ґрунтах різних моніторингових ділянок перевищував контрольні значення у 5,5-5,9 разів. Аналіз результатів досліджень дозволив встановити, що ґрунти спустошених земель Петровського відвалу характеризуються несприятливими властивостями для росту більшості видів деревних рослин.

Ключові слова: ґрунт, девастовані землі, відвали гірських порід, макронутрієнти, важкі метали, валові форми, фітотоксиканти, фітооптимізація

Introduction.

Devastated lands are the surface new formations, where the soil and vegetation cover have been completely destroyed, and anthropogenic morphosculptures (medium or small forms of relief that have arisen under the influence of exogenous factors of technogenic genesis) have been formed. Now these lands are an integral component of the mining and metallurgical areas at Ukraine, at Europe and at Worldwide (Savosko, 2011; Adams, 2017; Bielyk, et al., 2019). Numerous studies have convincingly proved that such lands pose a serious threat to human safety and well-being, since they are a source of intense secondary pollution of atmospheric air, soil, surface and ground waters of adjacent territories. In addition, devastated lands generate the spread of weed, allergenic and invasive plant species in the regions of their deployment (Macdonald, et al, 2015; Pietrzykowski, 2019; Masiuk et al., 2020). These problems are exacerbated by a significant area of devastated land: more than 2 000 000 hectares in the world, about 200 000 hectares in Ukraine and about 100 000 hectares in Germany (Wong, 2003; Savosko, 2011; Kivinen, 2017; Shvaiko & Manyuk, 2017). Therefore, the development of effective, but inexpensive technologies for optimizing devastated lands is urgent.

Recently, numerous studies have been aimed at finding the innovative ways to optimize the territories of devastated lands (Skousen & Zipper, 2014; Shvaiko & Manyuk, 2017; Zipper, et al., 2011; Savosko, et al., 2019a). Since the classical technology of their reuse (reclamation / revitalization) does not stand up to criticism in the framework of modern research (Savosko, 2011; Skousen & Zipper, 2014; Adams, 2017; Kivinen, 2017). According to experts, the creation of the artificial tree plantations is the most promising way to restore the devastated lands (Adams, 2017; Macdonald, et al, 2015; Ranjan, et al, 2016; Savosko & Tovstolyak, 2017). However, the ecological conditions of these territories are very unfavorable for most species of ornamental woody (Savosko, 2011; Bielyk, et al., 2019; Pietrzykowski, 2019), fruit (Shcherbyna, et al., 2017; Khromykh, et al., 2018) and agricultural plants (Nazarenko & Lykholat, 2018; Nazarenko, et al., 2018; Palchykov, et al., 2019).

In most cases, the formation of a fragmented soil cover on the devastated lands was established, which is characterized by a thin profile, an insignificant content of humus and macronutrients, an unfavorable reaction of the soil solution, and the presence of an excessive content of phytotoxicants (Savosko, et al., 2018; Bielyk, et al., 2019; Savosko, et al., 2019b). It has been shown that such properties of the soil cover adversely affect the state of the organism of animals (Lykholat, et al., 2019; Pokhylenko, et al., 2019) and humans (Pertseva, et al., 2012; Lykholat, et al., 2019).

For woody plant species, one of the most significant environmental condition is the insufficient amount of leading macronutrients (nitrogen, phosphorus, potassium, etc.) in the soils of devastated lands, which predetermine the growth and development of these species (Adriano, 2001; Dobrovolskij, 2003; Bradl, 2005; Kabata-Pendias, 2011; Maathuis, 2019).

It should be noted that the heavy metals are among the priority phytotoxicants (Komarova, 2015b; Yakun, 2016; Antoniadisa, et al., 2017; Podolyak & Karpenko, 2019). Heavy metals in small concentrations are the actual trace elements for all living organisms (Adriano, 2001; Dobrovolskij, 2003; Sparks, 2003; Sposito, 2008), but a significant excess of their content in the soil has a negative effect on the growth and development of woody plant species (Ding, et al., 2015; Khalid, et all., 2017; Pogrzeba, et al., 2019).

Therefore, the urgent task is to study the chemical composition of the soil of devastated lands, and first of all, to identify the actual concentrations of the leading macronutrients (as potential nutrients for plants) and heavy metals (as potential phytotoxicants).

Purpose of the work: *t*o conduct a comparative analysis of the gross forms content of macronutrients and heavy metals in the soils of devastated lands of the Kryvyi Rih mining and metallurgical region.

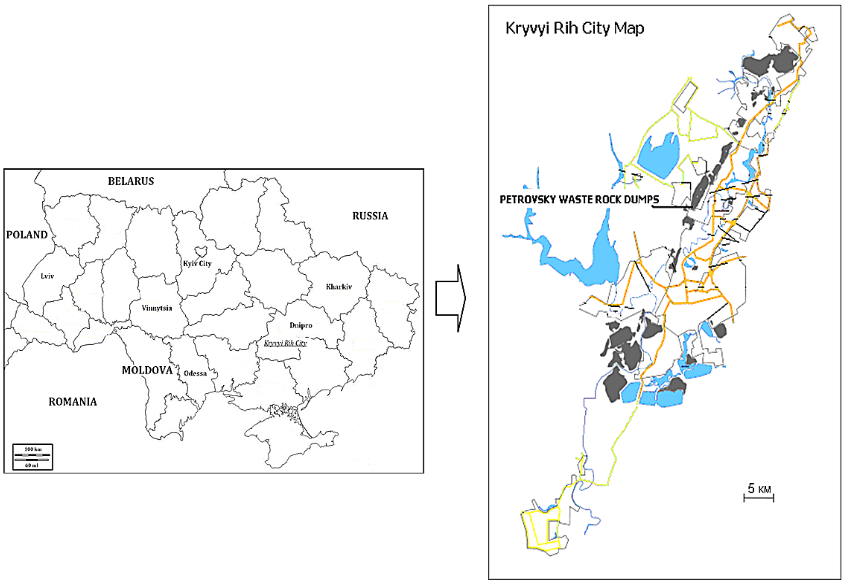
Materials and research methods.

The materials for the article were the results of research that were carried out at the Petrovsky waste rock dump, Central part of the Kryvyi Rih Iron Mining & Metallurgical District, Dnipropetrovs'k oblast, Ukraine (Fig. 1).

The Petrovsky waste rock dump was formed as a place for storing the unpromising iron ores, quartzite and loose rocks. In this dump the ecological conditions for the growth and development of plants are typical for the Kryvyi Rih region, which is due to the composition of rocks, their age and area (Savosko, et al., 2018; Bielyk, et al., 2019).

On the territory of the Petrovsky waste rock dump, five monitoring sites were selected, which differ in the age of the rock dump and are characterized by contrasting edaphic conditions. The control plot is located at a distance of 30 km from the industrial enterprises of the region in the Gurovsky forest (Dolinsky district, Kirovograd oblast).

At each plot, soil samples were taken from the top layer at a depth of 0 – 10 cm in accordance with classical sampling techniques. The procedures for soil samples drying, grinding and sifting through a metal



Map of the Petrovsky waste rock dumps

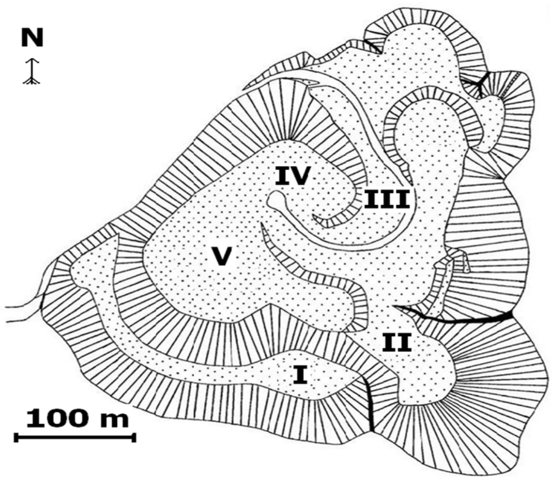


Fig. 1. Location of study area and structure of the Petrovsky waste rock dumps: I, II, III, IV, V – numbering of the monitoring plots

sieve (mesh size 1 mm) were carried out according to standard methods (Stehman, et al., 1999; Pansu & Jacques, 2006; Tykhonenko, et al., 2009). Briefly, 20 mg of a mixture of Na_2CO_3 and K_2CO_3 (ratio 1:1) was added to 100 mg of the soil sample and mixed thoroughly. The resulting mixture was placed in a muffle furnace and kept at a temperature of 700 ºC for 5 hours. The cooled samples were dissolved in a mixture of acids (HF and HCl), and an aliquot was taken (Stehman, et al., 1999; Pansu & Jacques, 2006).

Determination of the macronutrients content (potassium, sodium, calcium, magnesium, sulfur and phosphorus) and the heavy metals (iron, manganese, zinc, copper, lead and cadmium) was performed using the Inductively Coupled Plasma Mass Spectrometry (ICP-MS) X-Series 2 (Thermo Fisher Scientific, USA). Laboratory studies were carried out at the Institute of Biosciences, Freiberg University of Technology and Mining Academy (Freiberg, Germany).

The content of macronutrients (MN) and heavy metals (HM) in the soil samples was expressed in ppm dry weight. The results obtained were processed using the methods of variation statistics; differences between the comparison groups were considered significant at the level of statistical significance $P < 0.05$ (McDonald, 2014).

Results.

Content of MN and HM in the soils of the control plot. We found that in the soils of the control plot, the potassium content ranges from 1.10% to 1.33%, with an average value of 1.22 ± 0.04 % (Table 1). According to scientific literature (Perelman, 1989; Alekseenko, 2000; Chertko & Chertko, 2008), the average potassium content in soils ranges from 1.36 % to 4.20 %. Orlov (1992) showed that in the chernozem soils, the content of this element is 1.32 % (typical chernozems), 0.97 % (ordinary chernozems), and 1.75 % in southern chernozems.

In accordance with the results of our studies, the sodium concentration in the soils of the control plot varied in the range 0.65 – 0.83 %, with an average value of 0.70 ± 0.03 %. Scientific publications (Perelman, 1989; Alekseenko, 2000; Chertko & Chertko, 2008;) indicate that the optimal sodium content in soil ranges from 0.63 % to 2.84 %. According to Orlov (1992) data, the amount of sodium in chernozem soils reaches the following values: 0.57 % in typical chernozems, 0.44 % in ordinary chernozems, and 1.19 % in southern chernozems.

The calcium content in the soils of the control plot fluctuated from 3.11 to 3.74 %, the average value was 3.41 ± 0.11 %. Literature sources (Perelman, 1989; Alekseenko, 2000; Chertko & Chertko, 2008;) indicate that the average concentration of calcium in soils is 0.51 – 2.53 %. In the chernozem soils (Orlov, 1992), the content of this element reaches 2.47 % in typical chernozems, 4.20 % in ordinary chernozems and 2.10 % in southern chernozems.

According to our research, the magnesium concentration in the soils of the control plot ranged from 1.86 % to 2.57 %, with an average value of 2.06 ± 0.14 %. Previous studies (Perelman, 1989; Alekseenko, 2000; Chertko & Chertko, 2008) have found that the average magnesium content in soils is in the range of 0.16 – 1.37 %. In typical chernozems, the concentration of this element comprises 1.01%, in ordinary chernozems 1.19 %, and in southern chernozems only 0.95 % (Orlov, 1992).

The sulfur concentration in the soils of the control plot varied in a narrow range from 0.75 % to 1.309 %, with an average parameter value of 0.89 ± 0.06 %. Scientific publications (Perelman, 1989; Alekseenko, 2000; Chertko & Chertko, 2008) indicate that soils usually contain from 0.03 % to 0.085 % sulfur. According to Orlov (1992), the amount of sulfur is 1.69 % in typical chernozems, 0.22 % in ordinary chernozems, and 0.17 % in southern chernozems.

We found that the phosphorus content in the soils of the control plot ranges from 0.09 % to 0.13 %, with an average value of 0.11 ± 0.01 %. It is known that the average phosphorus content in soils is insignificant and amounts to 0.06 – 0.08% (Perelman, 1989; Alekseenko, 2000). The concentration of this

Table 1. Total content of the macronutrients in the soils of the control plot, %

Statistical parameters	Macronutrients					
	Potassium	Sodium	Calcium	Magnesium	Sulfur	Phosphorus
Minimum value, Min	1.10	0.65	3.11	1.86	0.75	0.09
Maximum value, Max	1.33	0.83	3.74	2.57	1.09	0.13
Average value, M	1.22	0.70	3.41	2.06	0.89	0.11
The absolute error of the arithmetic mean, m	0.04	0.03	0.11	0.14	0.06	0.01
Variation coefficient, V%	15.76	21.19	14.12	29.43	31.43	28.75

element in chernozem soils reaches 0.10 % in typical chernozems, 0.07 % in ordinary chernozems, and 0.06 % in southern chernozems (Orlov, 1992).

In our studies, it was found that in control plot soils the iron content varied from 3.92 to 4.75 %, with an average value of 4.25 ± 0.18 % (Table 2). The iron content in conventionally clean (uncultivated) soils comprises 0.47 – 4.30 %, and in the cultivated soils 1.40 % – 2.80 % (Bradl, 2005; Kabata-Pendias, 2011). The following concentrations of this metal were revealed in chernozem soils: in typical chernozems 3.69 %, in ordinary chernozems 3.04 %, and in southern chernozems 3.50 % (Orlov, 1992).

According to the scientific literature review (Bradl, 2005; Kabata-Pendias, 2011), the concentration of manganese in the untreated soils is detected in a very wide range of 60 – 1100 ppm, and in cultivated soils it varies from 990 to 7400 ppm. In the chernozem soils, the concentrations of this metal are as follows: 500 ppm in typical chernozems, 200 ppm in ordinary chernozems, and 500 ppm in southern chernozems (Orlov, 1992). We found (Table 2) that the content of manganese in the soils of the control plot is slightly higher than in chernozem soils (705 – 810 ppm, with an average value of 761.7 ± 18.02 ppm), but does not exceed the data established for the cultivated soil.

The concentration of zinc in uncultivated soils reaches 25 – 65 ppm, and in cultivated soils, 37 – 680 ppm (Bradl, 2005; Kabata-Pendias, 2011). According to the results of our research (Table 2), the zinc content in the soils of the control plot (85 – 98 ppm, with an average value of 90.51 ± 2.73 ppm) coincides with the published data for the cultivated soils.

The copper content in the uncultivated soils varies in the interval 8.70 – 33 ppm, while in cultivated soils, the concentration of this metal rises to 9.90 – 39 ppm (Bradl, 2005; Kabata-Pendias, 2011). We found (Table 2) that in the soils of the control plot, the copper content (26.84 – 30.15 ppm, the average value is 18.73 ± 0.78 ppm) does not go beyond the indicated ranges.

The average lead content in cultivated and uncultivated soils is 2.60 – 26.0 ppm (Bradl, 2005; Kabata-Pendias, 2011). The analysis of the obtained results showed (Table 2) that the concentration of this metal in the soils of the control plot (from 26.84 ppm to 30.15 ppm, with an average value of 28.10 ± 0.60 ppm) was slightly higher than these values.

Similar patterns were revealed for cadmium, the content of which in the background soils is 0.10 – 0.13 ppm (Bradl, 2005; Kabata-Pendias, 2011). The concentration of this metal revealed in the soils of the control plot exceeded the indicated level, varying in the range from 0.1 ppm to 0.19 ppm with an average value of 0.16 ± 0.01 ppm (Table 2).

Table 2. Total content of heavy metals in the soils of the control plot

Statistical parameters	Heavy metals					
	Iron	Manganese	Zinc	Lead	Copper	Cadmium
	%	ppm				
Minimum value, Min	3.92	705.84	84.62	17.80	26.84	0.11
Maximum value, Max	4.75	810.79	98.25	21.85	30.15	0.19
Average value, M	4.25	761.70	90.51	18.73	28.10	0.16
The absolute error of the arithmetic mean, m	0.18	18.02	2.73	0.78	0.60	0.01
Variation coefficient, V%	18.7	10.58	13.48	18.75	9.53	36.94

Content of MN and HM in the soils of devastated lands. The analysis of the obtained results showed that in the soils of the devastated lands of the Petrovsky dump, the potassium content varied in the range from 1.13 % (plot IV) to 1.39 % (plot I), with an average value of 1.26 %. The revealed concentrations of this macronutrient were less than its content in the lithosphere and the Earth's crust, but higher than in ultrabasic and basic rocks (Perelman, 1989; Alekseenko, 2000; Chertko & Chertko, 2008).

It should be noted that a statistically significant excess of the control potassium content (13 % higher than the control, $P < 0.05$) was found only on the monitoring plot I (Fig. 2). At the same time, in sites II, III and IV, the concentrations of this macronutrient were at the level of control values, and on plot V concentration was slightly lower (by 8 %, $P < 0.05$).

We found that the concentration of sodium in the soils of devastated lands ranged from 0.64 % (plot V) to 0.77 % (plot I), with an average value of 0.74 %. These values are below the amount of this element in the Earth's crust and lithosphere, but close to the sodium levels found in shales and clays.

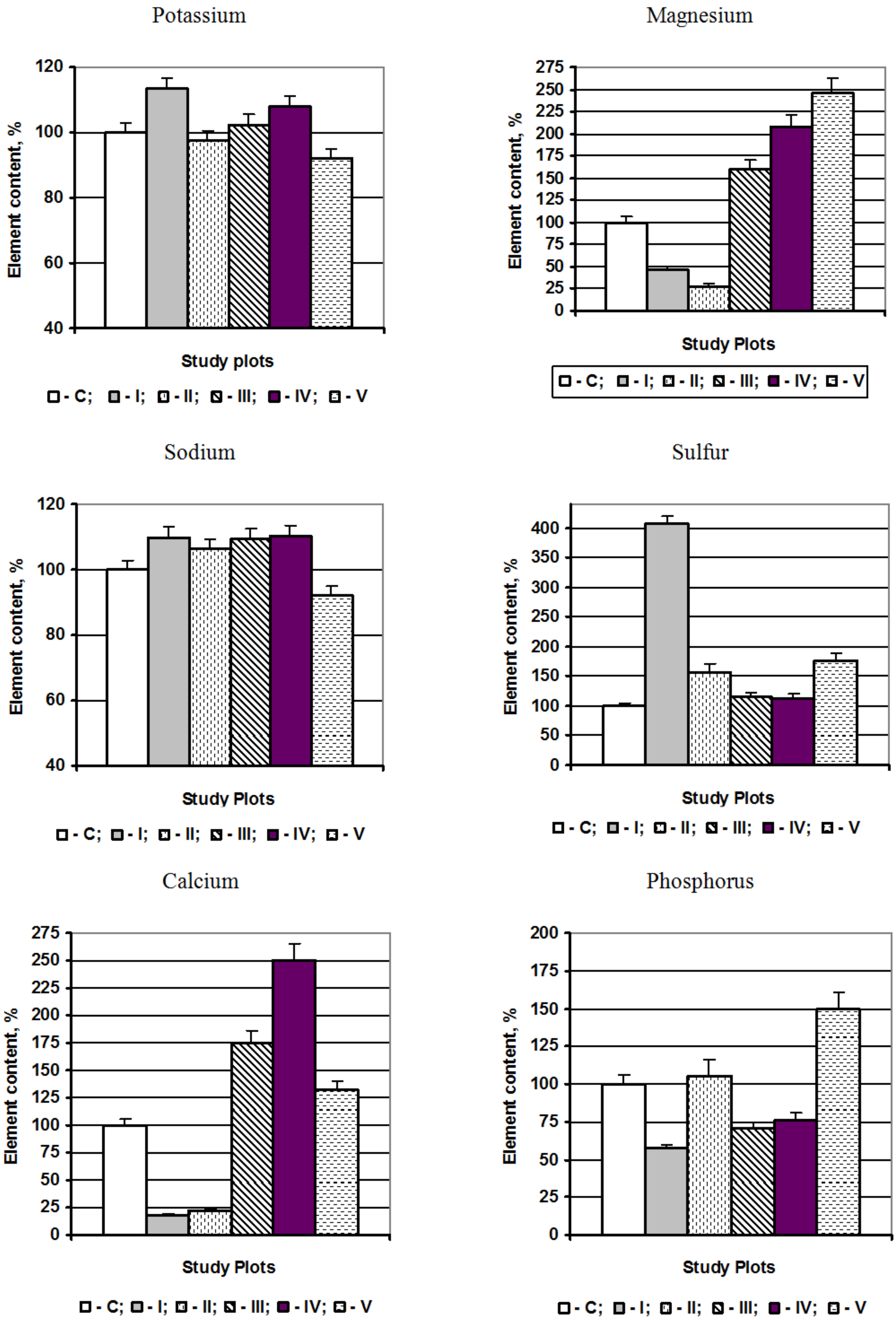


Fig. 2. Comparative content of the macronutrient's total forms in the soils of the devastated lands at Kryvyi Rih District
The content of the elements in the control is taken to be 100%.
Research areas: C – control; I, II, III, IV, V – monitoring sites of the devastated lands

The sodium content in the soils of the devastated lands was 6 – 10% (P <0.05) higher than the control level (Fig. 2). The exception is the soils of plot V, where the concentrations of this element were 7 – 8% (P <0.05) below the control value.

Calcium concentrations in the soils of the Petrovsky dump were determined in a very wide range of values: from 0.61 % (plot I) to 8.56 % (plot IV), with an average value of 4.08 %. Such content of this macronutrient corresponds to its Clarke in the Earth's crust, lithosphere, and in most rocks (Perelman, 1989; Alekseenko, 2000; Chertko & Chertko, 2008). Compared with the control, calcium concentrations on the plots I and II were lower by 4.5 – 5.6 times (P <0.05), while on the plots III, IV and V they were higher by 1.3 – 2.5 times (P <0.05).

The range of magnesium content in the soils of devastated lands was also very wide: from 0.57 % (plot II) to 5.08 % (plot IV), with an average value of 2.83 %. These values of magnesium content correspond to its Clarke values in the Earth's crust, lithosphere and basic rocks. It was found (Fig. 2) that on the plots I and II, magnesium concentrations were 3.6 and 2.2 times lower than the control values, respectively (P <0.05), while in the rest of the sites they exceeded the control by 1.6 – 2.5 times (P <0.05).

The results of our research (Fig. 2) indicate that phosphorus concentrations in the soils of the devastated lands of Kryvorizhzha vary from 0.06 % (plot I) to 0.17 % (plot V), with an average value of 0.10 %. Such levels of this element correspond to its Clarkes in the Earth's crust, lithosphere, and basic rocks (Perelman, 1989; Alekseenko, 2000; Chertko & Chertko, 2008). The amount of this macronutrient on the plots II and V was 7 – 49% higher than the control (P <0.05), while on the plots I, III and IV it was 24 – 44% lower (P <0.05).

The sulfur content in the soils of the Petrovsky dump varied from 1.02 % (plot IV) to 3.65 % (plot I), with an average amount of 1.73 %. Such concentrations of this element significantly exceed its Clarke in the Earth's crust, lithosphere and leading rocks (Perelman, 1989; Alekseenko, 2000; Chertko & Chertko, 2008). Therefore, it is quite natural that the amount of sulfur in the soils of devastated lands was higher in comparison with the control values: 1.1 – 1.6 times (P <0.05) on the plots II, III, IV and V, and 4.1 times higher on the plot I (P <0.05).

The revealed values of calcium and magnesium in the soils of the plots I and II indicate a serious deficiency of these macronutrients (2 – 5 times lower than the control values). In the remaining plots, there is probably an excess amount of calcium and magnesium in the soils (1.3 – 2.5 times higher than the control). In the soils of all monitoring sites, increased sulfur content in comparison with the control values was revealed. On the plot I, high concentrations of this macronutrient (4.1 times higher than the control) may have a phytotoxic effect on woody plant species. The phosphorus concentration was at the control level only on plot II, while on the plots I, III and IV it was significantly higher than the control (by 24 – 42%), and on plot V it was 1.5 times lower than the control values.

The analysis of the obtained results showed that the iron content in the soils of the devastated lands of the Petrovsky dump varies from 5.70 % (plot IV) to 11.12 % (plot V), with an average value of 9.54 %. Such concentrations of this metal exceed its Clarkes in the lithosphere, Earth's crust and in the main rocks (Perelman, 1989; Alekseenko, 2000; Chertko & Chertko, 2008). In comparison with the control values (Fig. 3), the iron content in the soils of all monitoring sites was significantly (P <0.05) higher by 1.4 – 2.6 times.

The concentration of manganese in the soils of the devastated lands ranged from 884 ppm (plot II) to 1030 ppm (plot V), with an average value of 962 ppm. Such concentrations of this metal are somewhat higher than its Clarks in the Earth's crust and lithosphere (Alekseenko, 2000; Chertko & Chertko, 2008; Perelman, 1989). In comparison with the control level, the concentration of manganese in the soils of all plots was significantly (P <0.05) higher by 16 – 35 % (Fig. 3).

The results of our research indicate that the concentration of zinc in the soils of the devastated lands of the Petrovsky dump varied from 77.1 ppm (plot I) to 127 ppm (plot V), with an average value of 92.4 ppm. These levels of element correspond to its Clarkes in the Earth's crust, lithosphere and basic rocks (Alekseenko, 2000; Chertko & Chertko, 2008; Perelman, 1989). The amount of zinc in the soils of devastated lands of the Petrovsky dump differs from its control values (Fig. 3). On the plots II, III and V, the amount of this metal was 8 – 14 % lower than the control (P <0.05), while on plot IV it was 1.41 times higher than the control level (P <0.05).

The copper content in the soils of the devastated lands of the Petrovsky dump varied in the range of 25.07 ppm (plot IV) – 32.96 ppm (plot V), with an average value of 28.82 ppm. Such concentrations do not exceed the Clarke values of this metal in the Earth's crust, lithosphere, and leading rocks, with the exception of ultrabasic rocks, sandstones, and carbonates (Alekseenko, 2000; Chertko & Chertko, 2008; Perelman, 1989). In comparison with the control values, the amount of copper in the soils of the Petrovsky dump at all monitoring sites was

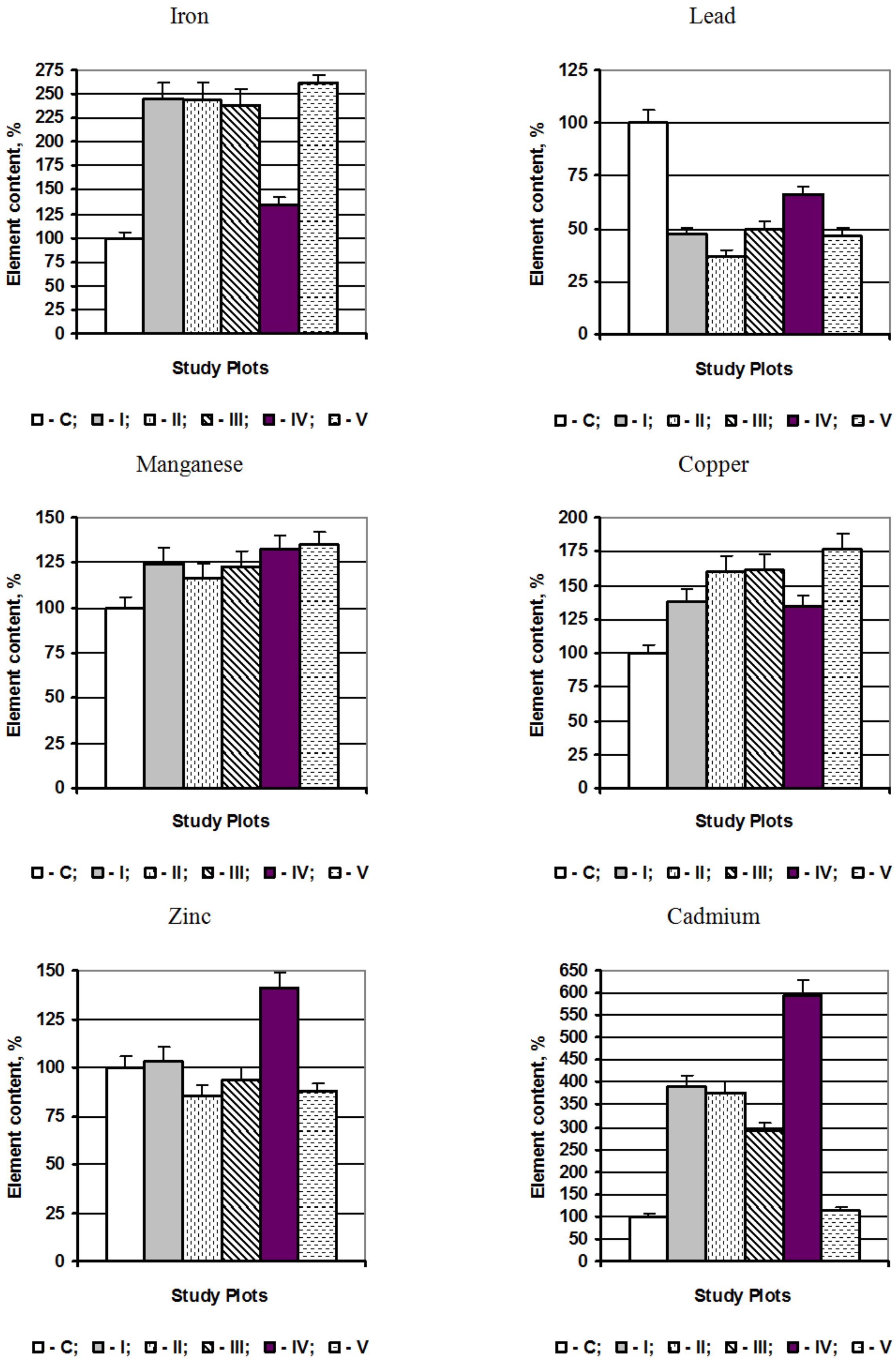


Fig. 3. Comparative content of the heavy metal's total forms in the soils of the devastated lands at Kryvyi Rih District
The content of the elements in the control is taken to be 100%.
Research areas: C – control; I, II, III, IV, V – monitoring sites of the devastated lands

significantly (P <0.05) higher by 1.3 – 1.8 times (Fig. 3).

Concentrations of lead in the soils of devastated lands were detected in a relatively small range from 10.9 ppm (plot II) to 18.60 ppm (plot IV), with an average value of 13.88 ppm. These metal levels are consistent with its Clarks in the Earth's crust, lithosphere, and leading rocks (Perelman, 1989; Alekseenko, 2000; Chertko & Chertko, 2008). The lead content in the soils of all studied plots significantly (P <0.05) was below the control level by 34 – 64% (Fig. 3).

The cadmium content in the soils of the Petrovsky dump varied from 0.18 ppm (plot V) to 0.95 ppm (plot IV), with an average value of 0.57 ppm. Such values of the element content are not anomalous, since they correspond to its Clarks in the Earth's crust, lithosphere, and basic rocks (Perelman, 1989; Alekseenko, 2000). In comparison with the control values, the amount of cadmium in the soils of all monitoring sites was significantly (P <0.05) higher by 1.1 – 5.9 times.

Discussion.

According to the results obtained, the soils of the control plot we chose were characterized by the typical regional content of the studied macronutrients (potassium, sodium, calcium, magnesium, sulfur and phosphorus). However, in comparison with chernozem soils in other regions, increased concentrations of calcium and magnesium were found. In our opinion, this may be due to the biogeochemical characteristics of the soils of the control plot. The revealed levels of macronutrient content in the soils of the control plot indicate their sufficient quantity for the growth and development of most species of woody plants.

In the soils of the control plot, only the concentration of copper was within the average values established for conditionally background, uncultivated soils. At the same time, the concentrations of other heavy metals (iron, manganese, zinc, lead and cadmium) were statistically significantly higher than the average values. We assumed that this phenomenon can be explained by the action of a regional geochemical and biogeochemical anomaly, which is characterized by an increased content of these metals.

The revealed patterns in the content of heavy metals in the soils of our control plot are consistent with the results of other studies carried out on the conditionally background areas of the Kryvyi Rih region (Savosko, 2009; Komarova, 2015a; Savosko, 2016) and the Dnipropetrovsk province as a whole (Gryshko et al., 2012; Tsvetkova et al., 2016). In our opinion, the increased content of biologically important metals (iron, manganese, and zinc) in the soils of the control plot may not be critical, but optimal for the growth of woody plant species.

The content of gross forms of macronutrients in the soils of the devastated lands of the Petrovsky dump was characterized by multidirectional differences from the control levels. The concentrations of potassium and sodium in the soils of the monitoring sites were at the level of control values or slightly exceeded them (by 10 – 13%). The exception is the soils of plot V, where the amount of potassium and sodium was slightly lower than the control (by 7 – 8%).

In the soils of the devastated lands of the Petrovsky dump, an increased content of gross forms of iron, manganese, copper, cadmium, and also zinc in some plots was revealed. The concentrations of these metals were by 1.2 – 5.9 times higher than the control values. It should be noted that, a lead content lower levels were revealed compared to the control (by 1.5 – 2.7 times). The zinc content in the soils of devastated lands characterized by multidirectional deviations from the control value. So, on the plots II, III, and V, the concentrations of this metal were slightly (by 7 – 14%) lower than the control; on plot IV they exceeded the control by 1.4 times, and on plot I they coincided with the control level.

Conclusion.

The soils of the devastated lands of the Petrovsky dump at all monitoring sites are characterized by very unfavorable conditions for the growth and development of most species of woody plants.

The concentrations of potassium and sodium in the soils of the devastated lands are mainly at the level of the control values. The content of calcium, magnesium and phosphorus in the soils of devastated lands indicates either a significant deficiency of these macronutrients (25 – 40 % lower than the control level), or their excessive amount (1.3 – 5.1 times higher than the control). In the soils of all monitoring sites, an excess of the control sulfur content was revealed (up to 4 – 5 times higher than the control).

The high content of gross forms of iron, manganese, copper, cadmium and, in some areas, zinc should also be attributed to unfavorable conditions at the monitoring sites of the Petrovsky dump. The concentrations of these metals in the soils of devastated lands exceed the control values by 5.5 – 5.9 times.

The established patterns of variation in the content of gross forms of macronutrients and heavy metals in the soils of the devastated lands of Kryvorizhzhya can be used in the development of innovative technologies for phyto-optimization of the territories of mining and metallurgical regions. In further studies, it is advisable to analyze the content of mobile forms of macronutrients and heavy metals in the soils of devastated lands, as well as their translocation into woody plants.

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Landscape geochemical conditions and patterns of inter-element redistribution of heavy metals in landscapes of Kivertsi National Nature Park "Tsumanska Pushcha"

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Abstract. Analysis of landscape geochemical conditions of the territory of Kivertsi National Nature Park "Tsumanska Pushcha" was carried out also the levels of pollution of landscapes within the park and adjacent territories were established. Features of the accumulation and distribution of pollutants in the landscapes of the territory under conditions of natural and Technogenic geochemical anomalies are considered. The landscapes of the studied migration classes (calcium, calcium carbonate, carbonate clayey, acidic calcium) are characterized by a relatively high coefficient of migration intensity due to relatively weak buffering capacity, low water retention capacity and contrasting moisture regime. However, strong gleyed horizons are able to fix contaminants during their surface movement. Using the methods of landscape geochemical research, analytical methods, data on the gross and mobile content of heavy metals were obtained and analyzed. The highest concentrations of manganese and chromium are found in soils differentiated on loess sediments, nickel and copper on glacial sediments. Most of the studied heavy metals exceed the regional geochemical background. In terms of the gross content in soils, trace elements form the following geochemical series: Zn>Cu>Pb>Ni>Mn>Cr. The accumulation of lead up to 2-3 MPC in forest litters is clearly traced. Dependences of the stability of landscapes to Technogenic pollution on the level of conservation of natural geochemical parameters of soils, the degree of their anthropogenic transformation and the level of heavy metals incomings have been established. All studied plants maximally accumulated Mn, Cu, Cr and minimally Zn and Ti which is consistent with the patterns of migration of these elements in the soil. The high accumulation of heavy metals in the aboveground part of the studied plants indicates a significant removal of elements from the soil, which, in turn, makes it possible to consider certain plant species as potential phytoremediators. According to the average values of the concentration of macro elements in plants, the following geochemical series is established: $CaO>K_2O>MgO>P_2O_5>SiO_2>SO_3>Al_2O_3>Fe_2O_3>Na_2O>TiO_2$. On the basis of the data obtained, 4 types of biogeochemical bonds between chemical elements in the soil – plant system for the territory of the NPP were identified: V, Ti - soil> plant; Ni - soil <plant; Cr - soil> plant; Mn, Cu - soil <plant.

Key words: heavy metals, forms of occurrence, intensity series, accumulations, landscape geochemical conditions

Ландшафтно-геохімічні умови та закономірності міжкомпонентного перерозподілу важких металів в ландшафтах Ківерцівського національного природного парку «Цуманська Пуща»

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Анотація. Здійснено аналіз ландшафтно-геохімічних умов території Ківерцівського національного природного парку «Цуманська Пуща» та встановлено актуальний рівень забруднення ландшафтів в межах парку та суміжних територій. Розглянуто особливості акумуляції та розподілу забруднюючих речовин в ландшафтах території в умовах природних і техногенних геохімічних аномалій. Ландшафти досліджуваних класів міграції (кальцієві, кальцієво-карбонатні, карботатноглейові, кислі кальцієві) характеризуються відносно високим коефіцієнтом інтенсивності міграції за рахунок відносно слабкої буферності, низької водоутримуючої здатності та контрастним водним режимом. Однак за наявності потужних оглеєних горизонтів спроможні фіксувати забруднювачі при їх поверхневому переміщенні. З використанням методів ландшафтно-геохімічних досліджень, аналітичних методів, отримано та проаналізовано дані про валовий та рухомий вміст важких металів. Найбільш високі концентрації марганцю та хрому мають ґрунти, що розвинуті на лесових відкладах, нікелю та міді на водноільодовикових відкладах. Більшість досліджуваних важких металів перевищує регіональний геохімічний фон. За валовим вмістом в ґрунтах мікроелементи формують наступний геохімічний ряд: Zn>Cu>Pb>Ni>Mn>Cr. Чітко простежується накопичення в лісових підстилках свинцю – до 2-3 ГДК. Встановлено залежності стійкості ландшафтів до техногенних забруднень від рівня збереження природних геохімічних параметрів ґрунтів, ступеня їх антропогенної трансформації та рівня надходження важких металів. Всі досліджені рослини максимально накопичували Mn, Cu, Cr і мінімально Zn та Ti, що узгоджується з закономірностями міграції цих елементів в ґрунті. Висока акумуляція важких металів у надземній частині досліджуваних рослин свідчить про значний виніс елементів з грунту, який, в свою чергу, дає можливість розглядати окремі види рослин як потенційні фіторемедіатори. За величиною середніх значень концентрації макроелементів у рослинах встановлено наступний геохімічний ряд: $CaO>K_2O>MgO>P_2O_5>SiO_2>SO_3>Al_2O_3>Fe_2O_3>Na_2O>TiO_2$. На основі отриманих даних виділено 4 типи біогеохімічних зв'язків між хімічними елементами в системі ґрунт-рослина для території НПП: V, Ti – ґрунт > рослина; Ni – ґрунт < рослина; Cr – ґрунт > рослина; Mn, Cu – ґрунт < рослина.

Ключові слова: важкі метали, форми знаходження, ряд інтенсивності, накопичення, ландшафтно-геохімічні умови

Introduction.

Most of the newly formed Ukraine's nature conservation objects are concentrated mainly territories, in the past they were actively used in economic activities and therefore are characterized by a significant anthropogenic transformation of landscapes. Analysis landscape geochemical environment is an integral part of the integrated area of research, especially in predicting the migration of contaminants. Geochemical studies of correlation dependences and types of connections of the leading components of landscapes of protected areas, their dynamics makes it possible to predict changes in the functioning of natural complexes determine their resistance to external influences and predict the behavior of pollutants in the natural environment. A reliable indicator of the ecological and geochemical state of the territory is the assessment of the distribution and migration of heavy metals (HM) in soils and in the soil-plant system.

Carrying out such comprehensive natural research is a necessary component of assessing the ecological state of protected areas. In particular, for national nature parks (NNP), where the functions of nature protection are combined with the recreational and economic use of territories. Therefore, for them, the task of landscape-geochemical analysis and the study of inter-component redistribution of heavy metals are especially urgent.

The main objective of the study to identify the features of migration and accumulation of pollutants in the landscapes of Kivertsi National Nature Park "Tsumanska Pushcha" in the conditions of natural and man-made geochemical anomalies.

The main objectives of the study:

1. To determine the landscape-geochemical conditions of the research territory and regularities of inter-element redistribution in the landscapes of Kivertsi NNP "Tsumanska Pushcha";
2. To determine the impact of man-made pollution on changes in the species composition of woody and herbaceous plants in the studied area.
3. Reveal the relationship between the content of heavy metals in the soil-plant system and establish the nature of the accumulation of heavy metals in the organs of woody plants.

Materials and methods of research.

The work used the factual material of field landscape geochemical studies carried out in the summer-autumn period of 2018-2019. During field studies, more than 1200 soil samples were taken. The total number of biogeochemical samples of the main NNP plants is more than 640 samples. Sampling was carried out throughout the NNP from the upper part of the humus horizon (0-10 cm) by the envelope method according to DSTU 4287: 2004. Soil samples, which are intended to determine the content of metals, are taken with instruments that do not contain metals. Sampling was carried out in good weather, in the morning before the onset of heat, or at the end of the day (at the same time) conditions for sampling from one polygon were the same. To study the distribution of trace elements along the soil profile, pits with a depth of up to 2 m were laid at individual test sites. Samples were taken every 10 cm of the soil profile. After sampling, the soils were dried; some were passed through a sieve with a 1 mm opening. Samples were quartered and selected for further analysis, which included: complete chemical analysis, analysis of gross content and mobile forms of trace elements, analysis of physicochemical parameters.

The analytical material presented in the article is obtained with the help of classical and modern analytical methods of analysis. Physics and chemical methods: atomic absorption method (spectrographs S-115, "Saturn-3") - used to determine the gross and mobile forms of trace elements in soils; emission spectral analysis (spectrograph "EST-1") - used to determine the content of heavy metals in soils and plants; chemical methods: method of mass spectrometry with inductively coupled plasma (ISR-MS analysis) on devices Elan-6100 and ICP-MS analyzer ELEMENT-2, made in Germany - was used for the determination of trace elements in soils and plants (Institute of Geochemistry, Mineralogy and Ore Formation named after M.P. Semenenko NASU and Institute of Geology of the Poland Academy of Sciences). The results of all the methods used were processed by the method of mathematical statistics and the mean value and interval values were calculated with a confidence level of 95-96%.

Plants were selected together with the root part, digging from the ground at different points of the monitoring sites (spot samples) (GOST 27262-87). Sod grasses were removed from the soil along with the soil monolith to avoid losing most of the root system. A combined sample was formed from plants belonging to one species. The combined sample of plants weighing 1.5 kg consisted of 8-10 spot samples. After selection, the plants were air-dried and crushed. The root part before grinding was pre-cleaned of soil particles to avoid getting them into the sample.

A total of 170 plant samples were analyzed. To detect the degree of absorption of heavy metals in the "soil - plant" system in the studied samples, a chemical analysis of the content of HM I (Pb, Zn), II (Ni, Cu, Cr) and III (V, Mn) hazard classes was performed.

The content of heavy metals in the phytomass of plants was determined in their ash solutions (dry ashing) by atomic absorption spectrometry using the CTE-1 instrument and by mass spectrometry with inductively coupled plasma (ICP-MS), ELEMENT-2 analyzer (Germany) at the Institute of Geochemistry, Mineralogy and Ore Formation NAS of Ukraine. Laboratories have certificates of certification and are provided with the necessary state standards and samples. During ICP-MS method it's used concentrated acids HF, HCl, HNO_3, H_2SO_4, H_3PO_4, which were further purified using the Sub boiling system. Samples were dissolved one by one in a mixture of hydrofluoric acid recommended for plant decomposition.

Quantitative assessment of toxic trace elements from the soil to plants was performed by calculating the coefficient of biological accumulation (CB), which is determined by the ratio of metal content per unit mass of the acceptor (plants in terms of its absolute dry weight and donor). To classify CBA, the studied elements were divided into five grades (Avessalomova, 1987):

1) elements of energy accumulation: CB - 10n and more;
2) elements of strong accumulation: CB - 10n;
3) elements of weak accumulation and average capture: CB - 0, n;
4) elements of weak capture: CB - 0,0n;
5) elements of very weak capture: CB - 0,00n and less.

Results and Analysis.

Landscape-geochemical structure of the park territory and its role in accumulation and redistribution of pollutants (heavy metals). Kivertsi National Nature Park "Tsumanska Pushcha" (Volyn region) formed from large forests near the village of Tsuman and a significant number (over 100) of small forest and meadow areas within the Kivertsi district (total area of 34.5 thousand hectares). In the modern landscape structure of the investigated area dominated landscapes with varying degrees of anthropogenic changes.

When combining landscapes into geochemical classes, the general physicochemical characteristics of soils were taken into account, which determine the patterns of migration of elements in the landscape as a whole. Since the humus horizon of soils is characterized by the highest intensity of all geochemical processes occurring in the landscape, it is its characteristics that are taken as a basis for analyzing landscape-geochemical conditions. The following physicochemical parameters of soils were determined: the content of individual ions, pH of the water extract, pH of the salt extract, determination of the hydrolytic acidity, etc. (Avessalomova I.A., 1978; Alloway, 1995; Vinohradov, 1957; Vorobiova et al., 1980; Zhovynskyi et al., 2012).

The data obtained by the authors (humus content, actual soil acidity, hydrolytic acidity, amount of absorbed bases) were used as the basis for combining the landscapes of the studied area according to the classes of water migration. Almost all geochemical landscapes of the NNP territory are characterized by the oxygen conditions of the soil solution, which is due to the presence of free oxygen. The exception is landscapes in which silty boggy soils are common, where gley restorative conditions are noted. The mineralization of soil solutions is usually low, less than 0.08%. Alkaline-acid conditions vary from slightly acidic to neutral (the pH value ranges from 4.2-5.1). Due to the following relatively homogeneous characteristics, considerable attention was paid to typomorphic ions dominating in the soils of different landscapes of the region: cations – Ca^{2+}, Na^{+} i K^{+}, and Mg^{2+}; anions – $[HCO_3]^-$, Cl^-.

Within the studied area, geochemical landscapes with such classes of water migration were identified:

Landscapes of acidic calcium (H-Ca, H-Ca|[H-Fe], H-Ca|H-Fe) classes.

Landscapes of acidic geochemical classes with a leading role of hydrogen ion H^+:

Acidic (H), acidic, acidic gley (H, H-Fe), and acidic gley (H-Fe);

Landscapes of calcium (Ca) and calcium carbonate ($CaCO_3$) classes;

Landscapes of acidic calcium (H-Ca, H-Ca | [H-Fe], H-Ca | H-Fe) classes.

Landscapes of acid geochemical class. Relief-forming rocks are water-glacial and alluvial sediments, mainly sandy mechanical composition. Low concentrations of micro- and macronutrients in soil-forming rocks cause soil depletion, which leads to a deterioration of the mineral nutrition of plants.

The results obtained indicate that the soils are depleted in both chalcophilic and siderophilic elements, for most of which there is a level of extreme deficiency (concentration ratio Kk <0.3). Particularly low concentrations are characteristic of chromium and nickel.

Soddy-podzolic and slightly podzolic clayey sandy and soddy-podzolic clayey-sandy loamy soils are most widespread within the studied area. Often, due to the weakening of the soil runoff, in the soils there are signs of deep gleying in the form of a grayish-gray color of the lower part of the profile, during the transition from the illuvial horizons to the soil-forming rocks. The pH value in the upper part of the profile of such soils is acidic (pH = 3.7-4.1), gradually approaching slightly acidic with depth (pH = 4.9-5.2). The accumulation of humic substances is observed in the lower illuvial horizons. The maxim humus content of 2.1% was observed in the illuvial horizon, while in the eluvial horizon the content of humic substances varies from 0.3 to 1.0%.

The predominance of sandy rocks within the stud area also determines the main hydrochemical patterns. Low-mineralized surface waters were investigated, and in terms of total hardness they are characterized as “very soft” and “soft”. Surface waters have a reaction of the environment, varying over a wide range from acidic (4.6 pH) to neutral (7.1 pH). An acid reaction is typical for small rivers, which are fed in summer from swampy catchments. Surface waters are characterized by high iron content, which consistently exceed environmental standards, and in absolute terms is 0.5-2.7 mg/dm. Ground waters are characterized by a similar composition. The ionic composition of groundwater is dominated by bicarbonate ion, the content of which significantly exceeds the content of chloride and sulfate ions. Concentrations of hydrocarbonates and chlorides increase towards the backwater, the content of sulfates is maximal at the watershed. The concentrations of Na +, Mg + and K + Cations regularly increase from the watershed to the floodplain. Against the background of low concentrations of water-soluble salts, a high concentration of iron stands out sharply, which varies from 0.4 to 4 mg/dm. The lowest indicators of the content of other metals are characteristic of the transit landscapes of the river valley slope. According to the peculiarities of water migration, the elements are arranged in the following row: the elements of medium migration (0.2-1) include iron and nickel, the elements of strong migration in surface and groundwater (in descending order) - zinc, manganese, copper, lead. The obtained values for most trace elements are higher than the average values of water migration coefficients according to V.V. Dobrovolskyi, especially for lead, cadmium and manganese, which indicates their high mobility (1-10) in the conditions of acid reaction of soils and contrast redox conditions, weak expression of radial and lateral geochemical barriers (Dobrovolskyi, 1983).

Thus, the leading factors in the formation of soil composition in landscapes of acidic geochemical class are the dominance of sandy rocks of water-glacial origin, depleted by most elements and contrast redox conditions. Differences in the composition of soils are associated with the peculiarities of vertical and lateral migration of elements, accumulation on landscape-geochemical barriers.

The light particle size distribution of the described soils, low content of metabolic bases and humus do not contribute to the fixation of pollutants in the soil. That is why the landscape-geochemical characteristics of H-class landscapes are favorable for the accumulation of pollutants.

When groundwater lies close to the surface, soils with acidic glaciation (**H, H-Fe - class**) and low pH (less than 5.3) are formed. Landscapes of this class occupy insignificant spaces on denudation interfluve plains, composed of low-strength water-glacial sands and sandstones, with shallow marls and chalks, with sod-podzolic and sod-gley soils.

In the dominant soil types, the humus content is 1.5-1.7%, the acidity is high (pH 4.6–5.5), which strongly inhibits the development of biotic processes.

Soils have a higher absorption capacity in comparison with sand analogues: 6-8 mg-eq/100g of soil, but they are also characterized by higher hydrolytic acidity (2.0-3.7 mg-eq/100g of soil).

Sod-podzolic sandy soils are depleted microelements. The concentration of titanium averages (n × 10-3%) 53.7, manganese 18.76, copper 0.15, nickel 0.27, vanadium 0.89, chromium 0.51, lead 0.36, zirconium 27, 45. In the studied soils occur (n × 10-3%): molybdenum 0.1-0.2, niobium 0.8-1.0, scandium 0.5-0.8 and yttrium 0.8-2.0. The content of cobalt, bismuth, thallium, cadmium, tin, vanadium, below the sensitivity of the method.

The content of copper, chromium, nickel, exceeds the average level by 2-3 times. Metals, which are often considered as indicators of man-made emissions - lead and cadmium - in sod-slightly podzolic gley sandy-sandy soils are contained in small concentrations that do not exceed the average values for these soil differences. It is recorded that elevated concentrations are characteristic of siderophilic elements, chalcophilic accumulate weakly.

Soddy slightly-medium-podzolic soils, widespread on thick sandy water-glacial deposits, are characterized by a fairly uniform granulometric composition along the entire profile. Dominated by particles of Medium-grained sand with a size of 0.27-0.06 mm, which account for 87-94%. Their distribution by genetic horizons is usually homogeneous, with some decrease in the content of this fraction in the humus-eluvium and an increase in the illuminating horizons.

The amount of dust and physical clay varies between 2-5%.

Process of podsolization in these soils takes place in a fairly acidic environment. The lowest soil reaction is characteristic of the humus-eluvium horizon, pH 2.9-4.2, which is explained by the interaction with humus, which consists mainly of acidic products of organic sediment of coniferous species. Lower along the soil profile, the pH of the medium is in the range of 4.4-5.1. The low content of organic matter and the light granulometric composition of the soils determine the poverty of their absorbing complex. According to our data, in the humus-eluvium horizon of soils, the sum of absorbing bases on average reaches 8-10 mg-eq. per 100 g of soil.

When distributed over the genetic horizons, the number of bases and the capacity of the absorbing complex decrease which is due to a sharp decrease in the humus content with depth.

An insignificant increase in capacity of the absorbing complex in iluvial horizon occurs obviously due to the interaction of iron and aluminum compounds, which in the form of amorphous hydroxides; lingering in this horizon, partly enter the absorbing complex.

Iron, aluminum and silicon oxides play an important role in podzolic process. These compounds reflect the degree of mobility and forms of migration of elements and determine the concentration and migration of many trace elements. In the studied soils, the content of amorphous forms of iron varies between 0.03-0.20% (average 0.095%), aluminum - 0.04-0.55% (0.25%) and silicon - 0.06-0.90 % (0.23%). There is a decrease in the concentrations of amorphous compounds of iron and aluminum and an increase in the content of mobile forms of silicon in some soils from the highest relief elements to low. This situation is obviously due to changes in physicochemical processes in soils due to terrain, pH, humus and other factors.

H-Fe - class landscapes have high concentrations of iron and manganese, especially in deep soil horizons.

For manganese and copper there is an increase in concentrations in the illuvial horizon of the soil profile, which correlates with an increased number of amorphous compounds of iron and aluminum. Manganese is traced with organic matter, and nickel - with a heterogeneous source of its in. There are concentrations of lead in the humus-eluted horizon, which are associated with man-made input, because in the transition horizons it is not fixed. When considering the geochemical relationship of microelements with each other, a high positive relationship between Mn and Cu can be noted (when any fluctuation of the variable in the geochemical analysis of manganese is transferred to copper and amplifies, due to which continuous fluctuations arise in the interaction, indicates their high (positive) coefficient of interrelation), reliable relationship between Cu and Ni (multiple increase in one variable, which leads to an increase in the other and forms a positive relationship coefficient). Weakly interact with each other: Mn and Pb, Cu and Cr, Ni and Cr. For other pairs of trace elements, this relationship is insignificant.

Comparison of the average concentrations of trace elements in sandy soils in general showed that the soils of the park have an increased content of trace elements, especially zinc, copper and lead.

Landscapes of low above-floodplain terraced plains with meadow air-medium loamy gley soils have a humus content of 2.96% and a high content of exchangeable cations - 24.5 mg-eq./100g.

For low-level floodplains composed of sandy and loamy alluvium, with peat-swamp soils and peat lands, the content of microelements is highly variable. This indicates sharp differences in the conditions of the entry of microelements into peat deposits, their accumulation by plants and fixation on the peat biogeochemical barrier.

Concentrations of lead and nickel are close to the average values calculated for the studied area. The lead content in peat lands is not correlated with any of the other elements. A high reliable positive correlation was noted between the content of copper, nickel, iron and manganese in peat lands.

Landscapes of H, H-Fe-class are characterized by changing conditions of lateral migration of pollutants, which contribute to high mobilization of chemical elements. Due to the presence of thick gleyed horizons in the soil profile, landscapes with soils characterized by a heavy granulometric composition are capable of fixing pollutants (during their surface movement) on gley landscape-geochemical barriers (**LGB**). On sorption LGB fixation of pollutants occurs due to the high capacity of cation exchange and high humus content, and the variation of pH determines the fixing capacity of pollutants on LGB acid-base type.

Landscapes of calcium and calcium carbonate (Ca, $CaCO_3$) classes. Geochemical characteristics of this class of landscapes are associated with participation in the migration of carbonate rocks. Mobile calcium compounds determine the neutral and slightly alkaline reaction of the soil and the saturation of the absorbing complex of Ca and Mg. Such conditions contribute to the accumulation of humus.

Due to the increased biological accumulation, Cu, Mn, Pb, Zn accumulate in soils. Copper, manganese and lead have a positive correlation with the humus content, that is, they are contained in the soil in the form of complexes.

The wide distribution of landscapes of the calcium-carbonate class of water migration is explained by the superior carbonate rocks. In coniferous-broad-leaved and broad-leaved forest landscapes, while maintaining the zonal type of vegetation with a predominance of deciduous species, such geochemical conditions are also provided by the capacity and intensity of the biological cycle, as a result of which a large amount of calcium and organic matter gets into the soil every year with precipitation. Within the framework of the NNP and in the territories adjacent to the park, the landscapes of the calcium and calcium-carbonate class are, first of all, denudation plains, composed directly of dense carbonate rocks (marl and chalk), with soddy-carbonate and soddy-podzolic secondary carbonated sandy loamy soils formed on the weathering crust of chalk. The slopes of the denudation interfluve plains are inclined (3-50), composed of loess-like loams, underlain by chalk deposits, with soddy carbonate and podzolized black earth, light loamy, weakly fertile soils, characterized by high fertility (humus content 1.95-2.2%), are predominant among the exchangeable cations of Ca (20.82 mg-eq/100g), slightly alkaline reaction (7.3-7.5%) and strong fixation of substances and nutrients.

The floodplains of a higher level (2.7-3 m above the water line) are characterized by soddy calcareous sandy loamy soils, alluvial soddy sandy loamy and light loamy soils. They are also characterized by a high content of humus (up to 2.4%), the pH of the soils of these landscapes shifts towards neutral - 6.4-7.4. The content of exchangeable cations reaches 20-21 mg-eq/100g.

The conducted analysis of microelement composition shows that for alluvial sod layered soils there is a uniform distribution in the profile of copper, Nickel, chromium, and insignificant differentiation of manganese and lead content in eluvial-illuvial with accumulation in the turf horizon. In the distribution of zinc, there is a clearly pronounced minimum in the middle part of the profile, and accumulations in the lower, gleying part of the profiling.

Thus, the vertical distribution of trace elements in the landscape depends on a number of factors. Biogenic accumulation, which is characteristic of zinc, cadmium, and to a lesser extent manganese and lead, causes an increase in the concentrations of these elements in the soil cover.

In the landscapes of these classes, pollutants, namely heavy metals, have a low migration capacity and are almost never removed from the soil.

Landscapes of acidic calcium (H-Ca, H-Ca | [H-Fe], H-Ca | H-Fe) classes formed on low inter-river plains (185-195 m), composed of thin water-glacial sands and sandy loams, with shallow occurrence of marls and chalk, in conditions of sufficient and increased moisture. Such landscapes are characterized by a rather high amount of absorbed cations (18.75-24.4 mg-eq/100g) and humus (2.52-2.95%), acidity varies from neutral to weakly alkaline - 6.4-7.4. Soils of this class contain a significant number of silty particles (from 17% to 28%). Physical and chemical properties of soils cause biogenic accumulation of Zn, Cu, Mn and reduction of Co, Ni removal.

Landscapes of these classes are characterized by a relatively high coefficient of migration intensity due to relatively weak buffering, low water holding capacity and contrast water regime. However, in the presence of strong gleyed horizons are able to fix pollutants during their surface movement.

Content of toxic elements in the landscapes of National Natural Park "Tsumanska Pushcha".

It has been established that the indicators of the accumulation of heavy metals in soils of the NNP are significantly higher than average data for Kivertsevski district of the Volyn region.

Anthropogenic impact, in addition to agricultural activities, associated here with large enterprises, in particular PJSC "Tsuman", LLC "Tanforan", LLC "Kaminskiy Timber and Venuses", "Ukrlesservice", spontaneous dump of Tsumansky production department of housing and communal services p.g.t. Tsuman and Kadysche village), PAF "Vistula", "Lutskvodokanal", etc.

Wastes of enterprises are substances of I - IV classes of danger. In particular, waste containing aluminum, vanadium, chromium and their compounds, lead (including Batteries for storage purposes or broken ones), iron carbonyls, etc.

Most of the studied HM exceeds the regional geochemical background. Migration and spreading of each metal along the profile of Soddy weakly - medium podzolic soils has its own specifics. The greatest accumulation of copper and zinc occurs in forest litters, and in mineral part of the profile it has a weakly expressed eluvial-iluvian character. Content of nickel, cobalt and manganese become increases with depth of its accumulation in soil, which are characteristic of the chemical composition of glacial sediments (*Lubben et al., 1991; Sauerbeck et al., 1991*).

It is noted that the amount of chromium, manganese and cobalt is higher in soil-forming rocks than in forest litters. Spreading along the profile of chromium, no regularities were found. The average HM content in the main soil types of the NNP territory is presented in Tables 1 and 2.

By gross content of micronutrients in soil we can arrange in the following series of geochemical: Zn> Cu> Pb> Ni> Mn> Cr. Accumulation of lead in forest litters up to 2-3 LOC is clearly traced.

Obtained data about accumulation of heavy metals in soils of the NNP territory are of significant importance, since they are the basis for identifying spatial patterns of soil pollution and establishing the local geochemical background.

Most of heavy metals are spread unevenly in the soil cover. High values of the coefficient of variation (V) - more than 34% typical for heterogeneous set of data on concentration of all studied HMs (Table 5). The highest rate of variation was found for lead concentration - 170%, and the lowest values were obtained for content of chromium - 34% and zinc - 36%.

To characterize the average content of heavy metals in the soils of the NNP, the arithmetic and

Table 1. Average HMs indicators in genetic bedding rocks of soil, most typical for the territory of NNP

Bedding rock, depth	Mn	Pb	Cr	Ni	Zu	Cu
Sod-slightly podzolic sandy on water-glacial sands and sand lined with Neogene-Paleogene sediments (sands and loams)						
Ho, 0-2 cm	430.0	38.0	23.2	26.2	274.7	23.5
HE, 2-4 cm	176.2	6.2	26.8	13.1	222.5	9.2
E, 4-20 cm	278.4	6.4	28.2	17.4	251.4	19.1
I, 20-60 cm	292.6	5.2	29.1	11.3	232.6	17.4
PI, 60-130 cm	271.5	6.0	19.2	11.7	221.8	18.6
Sod-medium podzolic sandy loam, on water-glacial sediments, with deep bedding of chalk rocks						
Ho, 0-2 cm	367.3	29.1	29.4	31.0	310.7	32.9
HE, 2-5 cm	259.0	7.9	34.2	23.6	227.4	11.2
E, 5-28 cm	383.6	7.0	34.1	26.3	254.9	11.7
I, 28-43 cm	510.3	5.1	38.6	25.4	267.1	14.2
IP, 43-124 cm	554.7	4.6	40.1	25.7	253.9	20.2
Peat-boggy on ancient alluvial sandy and loamy sediments						
THкор, 0-14 cm	362.9	19.6	28.3	27.6	341.3	29.3
HPк, 14-26 cm	341.5	10.2	37.5	24.3	320.5	15.7
Phкgl, 26-31 cm	346.2	13.4	44.3	26.3	343.1	17.4
P(h)кGl, 31-46 cm	362.5	9.0	43.2	25.4	346.8	19.2
Soddy carbonate sandy loam on eluvium of carbonate rocks						
Ho, 0-2 cm	320.4	38.3	26.3	26.0	494.3	22.2
Hк, 2-26 cm	280.6	27.5	34.4	24.3	363.9	16.4
Hрк, 26-43 cm	210.2	34.7	36.7	32.6	381.8	18.6
Pк, 43 > cm	168.6	24.2	34.3	31.8	382.0	21.2

geometric mean values were calculated. This is due to the fact that the indicators of the concentration of elements in soils vary greatly and do not obey the law of equable spreading. As a result, arithmetic mean strongly depends on the presence of small number of samples with higher levels of elements. In such cases, it would be more correct to use geometric mean to estimate the HM content in the soil *.

* Geometric mean N of numbers is equal to the root of the N degree from the product of these numbers, in this case - product of all obtained values of the content of a particular chemical element. Such an indicator is always less than arithmetic mean, in terms of its value, large deviations and fluctuations between individual values in the studied set of indicators are much less affected.

High value of the standard deviation (σ) is an indication of the average values of sporadic. Minim standard deviation was obtained for chromium concentrations - 30.5, and maxim for manganese 341.0.

Table 3 also presents characteristics of the average values of the HM content in soils of the NNP. The average content of all studied HMs exceeds their regional background values.

Table 2. Total content of micronutrients in the soils of NNP

Element	Average values	Limits of oscillation	K_{Ci}	Background values [9]	Average values	Limits of oscillation
	mg/kg				mg/kg	
	Content of gross forms				*Content of mobile forms*	
Mn	420	8.1-830	1.06	395	0.89	0.27-1.9
Cr	30.4	5.2-60.8	0.7	39	0.48	0.33-0.9
Ni	25.5	6.3-50.7	2.1	12	0.8	0.6-1.6
Zn	350	60.3-700	5	42	1.1	0.5-2.1
Cu	25.4	6.5-50.4	3.1	8	1.7	0.9-3.4
Pb	30.5	6.4-60.5	2.7	11	0.6	0.38-1.2

Table 3. Statistical indicators of HMs content in NNP soils, mg/kg

Element (background)	Arithmetic mean	Geometric mean	Maxim value	Minimal value	σ	V, %
Mn (395)	420	81.9	830	8.1	341.0	81
Pb (11)	30.5	19.6	60.5	6.4	52.1	170
Cr (39)	30.4	8.1	60.8	5.2	10.5	34
Ni (12)	25.5	17.8	50.7	6.3	11.6	45
Zn (42)	350	205.9	700	60.3	76.7	36
Cu (8)	29.4	19.8	60.4	6.5	21.4	72

General patterns of HM distribution in typical plants of the stud area.

The dependence of the HM content in NNP plants on the level of technogenic load and the properties of the soil cover of the territory. In connection with increases of heavy metals content in soil, their accumulation by plants increasing too. However, with distance from pollution sources, the content HM in plants decreases by 10-20 mg/kg. The excess content of Pb, Zn, Cu and Mn is detected in plants on constant test areas of NPP (points 17-19, 41-19), closest to the emission sources along the line of the prevailing wind direction. Differences in the content of metals in plants that grow under conditions of minim and maxim anthropogenic load, are for Mn and Zn - 6-7 times, Cu - 4-5 times, Ni and Pb - 4 times, Cr - 2 times. Similar trends in the accumulation and distribution of heavy metals in soils and plants during the two seasons of research in 2018-2019.

As a result of the study, the interdependence between the mineral composition of soils and the level of ash content of plants was established. The needles of Scots pine (Pinus sylvestris), which grows on sod-slightly podzolic sandy soils developed on glacial sands, has an average ash content of 3.25%, and alluvial sands - 1.52%, pine branches - respectively 2.81 and 1.68%, hanging birch leaves (Betula pendula) - 4.76 and 3.52%, branches 4.19 and 1.15%. There is a certain pattern - the richer the mineral composition of the soil, the higher the percentage of plant ash (Dobrovolskyi, 1983). In addition, despite the variability of ash content of plants growing in different landscape conditions, a direct relationship between soil chemical composition and ash content could not be detected. The average chemical composition of plants typical for the territory of the NNP species is presented in table 4.

Table 4. Chemical composition of plants typical the NNP species,% on ash, (ICP-AES)

Plants	SiO_2	Fe_2O_3	Al_2O_3	TiO_2	MnO	CaO	MgO	SO_3	K_2O	Na_2O	P_2O_5
Silver birch (Betula pendula):											
leaf	3.62	0.72	0.13	0.07	-	26.90	14.80	3.71	-	-	-
tree branches	1.67	0.74	1.51	0.06	0.41	39.87	5.71	1.84	7.11	0.85	5.93
Alder alder (Alnus incana):											
leaf	2.49	0.98	1.49	0.09	0.07	40.05	6.65	2.76	14.11	1.09	6.42
tree branches	3.61	0.69	1.83	0.09	0.39	43.86	3.12	2.14	6.65	1.75	2.89
Scots pine: (Pinus sylvestris)											
pine needles	3.21	0.41	4.07	-	-	13.02	17.22	4.21	-	-	-
tree branches	6.12	0.82	3.84	-	-	36.17	7.41	1.54	-	-	-
Hornbeam: (Carpinus betulus)											
leaf	2.43	0.61	0.92	-	-	35.01	5.26	2.34	-	-	-
tree branches	1.81	0.32	1.12	-	-	39.23	-	3.23	-	-	-
Raspberry (Rubus idaeus)	3.58	0.65	0.16	0.06	-	21.09	6.84	3.69	-	-	-
Shaggy sedge (Carex brizoides)	32.41	1.12	3.43	0.02	0.34	13.94	6.54	5.98	-	-	6.78
Wood pea (Lathyrus sylvestris)	31.76	1.78	0.73	0.17	-	7.60	7.09	-	-	-	5.02

It was found that in plants that are characteristic of the landscapes of floodplain terraces composed of ancient alluvial sands, with sod-hidden and slightly podzolic gley sandy and clay-sandy soils, for denudation interfluve plains and sandy loams, composed of low-thickness, with sod-podzolic and humus-carbonate clay-sandy and sandy soils, as well as for inter-annual plains composed of water-ice-sand sands and sandy loams, with deep deposits of marls and chalk, with sod-low-podzolic sandy loams and sandy loams the content of which ranges from 11.82 to 43.17%. The concentration of other elements is slightly lower. The following geochemical series can be established by the value of the average values of the concentration of macronutrients in plants: $CaO>K_2O>MgO>P_2O_5>SiO_2>SO_3>Al_2O_3>Fe_2O_3>Na_2O>TiO_2$.

The composition of mineral components differs slightly from the background landscapes of the landscapes of the erosion and river network, namely - beams with sloping slopes in water-glacial sands, and in sands lined with chalk deposits, with sod gleyed and meadow-swampy lowland soils level, composed of sandy and loamy alluvium, with peat-swamp soils. The latter are dominated by silicon oxide (up to 43%). The concentration of other elements in such landscape conditions forms the following geochemical series: $SiO_2>CaO>MgO>SO_3>P_2O_5>Al_2O_3>Fe_2O_3>TiO_2$. The content of CaO and SiO2 fluctuates in the highest percentages in plants (table 4).

The study of the most common species of plants growing on soils of different mechanical composition, found that the largest number of trace elements contain plants growing on sod-podzolic sandy-sandy soils, and the least on peat-swamp soils and peatlands (table 5).

In our opinion, this is due to the different intensity of plant uptake of elements. Plants that grow on soils poor in trace elements are characterized by greater intensity in terms of their absorption from the soil. Confirmation of the different intensity of plant uptake of elements from soils of different mechanical composition is the coefficients of biological absorption of the elements presented in table 6.

The largest amounts of plants absorb manganese, nickel and copper. Chromium and titanium are less

Table 5. The content of chemical elements in plants in their confinement to soils typical of the NNP area (average values for plants of different species, mg / kg), (ICP-MS)

Soil	Pb	Cu	Ni	Cr	Mn	Ti
Sod-slightly podzolic sandy on water glacial sands	9.6	18.9	5.8	2.7	360	28
Sod-weak (medium) podzolic sandy on water glacial sands	11.3	17.2	4.1	2.1	165	22
Sod carbonate light loam on forest-like loams	5.7	9.7	1.8	1.7	164	24
Alluvial layered sand on alluvial sands	8.3	13.5	3.5	1.3	67	11.3
Peatland low-power degradation	14.1	14.7	1.0	1.1	74	10.7

Table 6. The coefficient of biological absorption of plants growing on soils, typical (characteristic) for the territory of the NNP

Soil	Pb	Cu	Ni	Cr	Mn	Ti
Sod-slightly podzolic sandy on water glacial sands	2.37	34.8	8.32	1.34	33.16	0.39
Sod-weak (medium) podzolic sandy on water glacial sands	1.42	24.3	2.75	0.91	6.86	0.18
Sod carbonate light loam on forest-like loams	1.12	5.74	1.26	0.35	5.44	0.16
Alluvial layered sand on alluvial sands	0.78	21.76	3.57	0.41	6.25	0.08
Peat land low-power degradate	0.56	6.94	0.63	0.29	4.37	0.17

biologically active elements (Adriano, 2001; Andersen et al., 2004; Pinsky et al., 1989). They are characterized by rate of biological uptake of less than one. Smaller amounts of lead are absorbed, the amount of which in plants averages 12.4%. Manganese, titanium, nickel, copper and lead are present everywhere in plants.

It is established that plants that grow on sod-podzolic sandy soils are characterized by a high content of manganese, as well as copper and nickel. They are characterized by low titanium content. Plants growing on sod-podzolic sandy soils are characterized by low levels of chromium and titanium. However, they have an increased accumulation of copper, manganese and nickel.

For loamy soils, there are similar trends the accumulation of HM as in sandy soils, except for nickel. Based on the obtained data, 4 types of biogeochemical relationships between chemical elements in the soil-plant system for the territory of the NNP were identified: V, Ti – soil > plant; Ni – soil < plant; Cr – soil > plant; Mn, Cu – soil < plant.

HM content in woody shrub plants of the NNP territory.

The results of analytical studies of the geochemical composition of woody shrub plants NNP “Tsumanska Pushcha” (Table 7) show that in the largest quantities they accumulate **manganese**. The maximum concentration of the element was noted for Silver birch (Betula pendula) - 1020 mg / kg. For other plant species, the content of trace elements is much lower than the average: in samples of Scots pine (Pinus sylvestris), alder gray (Alnus incana) 2-3 times, sharp-leaved willow (Salix acutifolia) in 4 times.

Titanium maxim accumulates raspberry (Rubus idaeus) 80.0 mg/kg, aspen (Populus tremula) 60.3 mg/kg and hazel (Corylus avellana) 59.63. Interspecific differences in the content of the element reach 10-20 mg / kg.

The investigated NNP plants accumulate titanium in small quantities in comparison with the average values of the element content obtained for similar species of plants in the natural region as a whole. The average value of titanium in Ukrainian Polissia for pine is 21.2 mg/kg, in the park 3.80; for willow is 18.4 and 4.87, hornbeam - 25.2 and 4.87 mg/kg. From the bush vegetation, the increased content of titanium was found in samples of brittle buckthorn - 12.11 mg / kg (with average values of 3.4 mg/kg).

Differences in the average copper content between plants of different species are 10-14 mg/kg. High concentrations of this microelement are noted for common hazel (Corylus avellana) – 23.90 mg/kg, buckthorn brittle (Frangula alnus) – 21.37 mg/kg and raspberries (Rubus idaeus) – 20.3 mg/kg. Among woody plants, an increased copper content

Table 7. The average content of trace elements in woody and shrub plants NNP “Tsumanska Pushcha”, mg / kg, (ICP-AES)

№	Type of vegetation	Ash content, %	Mn	Cu	V	Pb	Ti	Cr	Zn	Ni
1	Scots pine (Pinus sylvestris)	3.25	290.7	6.41	0.89	0.93	3.80	1.32	-	2.78
2	Sharp-leaved willow (Salix acutifolia)	5.17	167.2	6.94	-	0.62	4.87	2.54	-	1.34
3	Silver birch (Betula pendula)	4.39	611.2	10.11	5.86	6.84	5.92	5.23	5.21	6.41
4	Alder alder (Alnus incana)	5.78	501.2	8.63	1.17	0.92	12.32	4.3	6.5	2.30
5	Hornbeam (Carpinus betulus)	4.11	532.6	5.69	5.87	2.61	4.87	5.96	-	-
6	Large-leaved cherries (Prunus avium)	4.87	563.1	-	4.87	-	5.23	4.34	-	3.26
7	Aspen (Populus tremula)	5.61	562.3	10.8	4.9	3.5	60.3	4.5	-	11.2
8	Hazel (Corylus avellana)	8.76	382.6	23.90	-	2.92	59.62	-	-	2.96
9	Buckthorn brittle (Frangula alnus)	9.11	889	21.37	4	1.36	12.11	4	9.3	3.61
10	Raspberries are common (Rubus idaeus)	7.64	860	20.3	3.4	-	80.0	3.5	50	-
	Background (Heavy metals in soils of Ukraine P, 2006)		277	13.5	3.4	5	-	3.6	-	2.6

was recorded for aspen (Populus tremula) - 10.8 mg/kg. It was determined that deciduous trees of the stud area contain slightly higher copper concentrations than conifers. The maxim concentration of copper in conifers is typical for Scots pine (Pinus sylvestris) - 8.7 mg/kg. In general, NNP plants accumulate copper by 5-8 mg/kg less than in the territory adjacent to the NNP.

The **nickel** content in plants is insignificant - mostly lower than background concentrations. Its maxim amount is observed in aspen (Populus tremula) 18.5 mg/kg, the average content is 11.2 mg/kg, the minimum in holly willow (Salix acutifolia) – 0.9 mg/kg at an average content of 1.34 mg/kg, which corresponds to the background content of the element. Among deciduous tree species in terms of nickel content, hanging birch (Betula pendula) differs and buckthorn brittle (Frangula alnus) (6.41 і 3.61 mg/kg accordingly).

The average content of **vanadium** in the ash of Scots pine (Pinus sylvestris) is 0.89 mg/kg, of deciduous trees - in the silver birch (Betula pendula) - 5.86 mg/kg, hornbeam common (Carpinus betulus) – 5.87 mg/kg and aspen (Populus tremula) – 4.9 mg/kg. The average content of vanadium in the analyzed samples is 2-3 times lower than the background values for plants of similar species.

The **zinc** content in most of the studied plants of the territory was below the sensitivity limit of the analysis. However, high levels of its content are recorded for raspberries (Rubus idaeus) – 50 mg/kg on sod podzolic gley sandy soils and brittle buckthorn (Frangula alnus) – 9.3 mg/kg on sod-slightly podzolic sandy soils near the village Yaromel.

The accumulators of lead are silver birch (Betula pendula), aspen (Populus tremula) and common hazel (Corylus avellana). The minim amount of trace elements is typical for specimens of willow (Salix acutifolia) - 0.5 mg/kg.

Coefficients of biological accumulation (CBA) of heavy metals by plants (table 8) calculated on the basis of the results of mass spectrometry analysis with inductively coupled plasma (ICP-MS), obtained for plant and soil samples of key areas of NNP.

For sod-slightly podzolic sandy soils of test areas 17-19, 23-19, 26-19 is characterized by a higher accumulation of HM plants compared to test areas 29-19, 41-19 due to the low buffering capacity of sandy soil. The value of KBP sandy soils is 1.5-5 times higher than in loamy soils.

The values of CBA on the sample areas located near the sources of pollution, in some cases were lower than in remote. Obviously, this is due to both the predominant uptake by plants of metals from the soil and the manifestation of the protective mechanisms of plants with increasing mobility of HM in the soil.

According to the value of the absolute HM content in the studied plants, the following geochemical series can be formed:

Sedge shaking (Carex brizoides):
Mn>Cu>Ni>Cr=Pb>V>Ti>Zn;

Common bracken (Pterídium aquilínum):
Ti>Mn>Cu=Pb=V>Cr>Ni>Zn;

Forest rank (Lathyrus sylvestris):
Mn>Ni=Cu>Pb>Cr=V>Zn>Ti;

Lily of the valley (Convallaria majalis):
Mn>Cu>Ni>Pb>V=Cr=Zn>Ti;

Raspberry (Rubus idaeus):
Mn>Pb=Zn=Cu=Ni>V=Cr>Ti;

Buckthorn brittle (Rhámnus frangula):
Mn>Cr>Cu>Pb>Ni>Zn>Ti>V;

Hazel common (Corylus avellana):
Cu>Mn>Ni>Cr>Pb=V>Zn>Ti;

Willow Sharp-leaved (Salix acutifolia):
Mn>Cr>Ni>V>Cu=Pb>Zn>Ti;

Aspen (Populus tremula):
Mn>Cr>Cu=V>Ni>Zn=Pb>Ti;

Male bugbug (Dryopteris filix-mas):
Cu>Mn>Ni>Pb>V=Cr>Zn>Ti;

Birch hung (Betula pendula):
Mn>Ni>V=Pb>Cu>Cr>Zn>Ti;

Yarrow (Achillea millefolium):
Mn=Ni>Pb=Cu>V=Cr>Zn>Ti;

Hornbeam (Carpinus betulus):
Mn>Cu=V>Ni=Pb>Cr>Zn>Ti.

It should be noted that there is not always a clear pattern between the values of the gross forms of HM and indicators of CBA. Probably, metal compounds adsorbed from the atmospheric air play an important role in the accumulation of HM by the aboveground part of plants. The plants that grow close to potential sources of contamination, We found a higher content of the test TM. The main part of the excess of the background values by elements was found on the test plots of the northwest direction. All studied plants accumulated as much as possible Mn, Cu, Cr and minimally Zn and Ti which is consistent with the patterns of migration of these elements in the soil (Vinohradov A.P., 1957).

Considering the distribution of elements in plants characteristic of the stud area, it can be stated that nickel is mostly accumulated in aspen (Populus tremula) (site 31-19) – 50 mg/kg, in the smallest amount accumulat by willow (Salix acutifolia) – 4 mg/kg on low-power peat lands in the floodplain of the Rudka River (site 30-19). The maxim content of manganese (800

Table 8. Coefficients of biological accumulation (CBA) of heavy metals by plants key areas of NNP «Tsumanska Pushcha»

№ site	Plant	Soil	The content of elements (mg / kg) in the plant (numerator, *or - the number from the top*) and in the soil (denominator *or - the number from the bottom*) biological accumulation coefficient (CBA)															
			Mn	**CBA**	**Ni**	**CBA**	**Ti**	**CBA**	**V**	**CBA**	**Cr**	**CBA**	**Zn**	**CBA**	**Cu**	**CBA**	**Pb**	**CBA**
16-19	Sedge shaking	Alluvial layered sandy loam	400		3		80		2		2		10		20		2	
	(Carex brizoides)		100	**4**	5	**0.6**	500	**0.16**	6	**0.3**	5	**0.4**	100	**0.1**	20	**1**	5	**0.4**
17-19	Bracken (Pterídium aquilínum)	Sod-slightly podzolic sandy	500		2		3000		40		4		100		6		30	
			300	**1.6**	6	**0.3**	300	**10**	40	**1**	10	**0.4**	600	**0.16**	6	**1**	30	**1**
23-19	Forest rank	Sod-slightly podzolic sandy	600		4		80		3		3		60		8		20	
	(Lathyrus sylvestris)		300	**2**	5	**0.8**	2000	**0.04**	10	**0.3**	10	**0.3**	600	**0.1**	10	**0.8**	40	**0.5**
24-19	Lily of the valley	Sod-medium podzolic sandy loam	800		2		60		2		2		20		10		15	
	(Convallaria majalis)		300	**2.6**	3	**0.6**	800	**0.07**	10	**0.2**	8	**0.2**	100	**0.2**	10	**1**	30	**0.5**
25-19	Raspberry (Rubus idaeus)	Sod podzolic sandy gleyey	1000		5		80		3		3		50		20		10	
			200	**5**	10	**0.5**	600	**0,1**	8	**0.3**	10	**0.3**	100	**0.5**	50	**0.4**	20	**0.5**
26-19	Buckthorn brittle (Rhámnus frangula)	Sod-slightly podzolic sandy	1000		2		10		4		4		10		19		7	
			200	**5**	6	**0.3**	400	**0.02**	300	**0.01**	8	**0.5**	200	**0.05**	40	**0.47**	16	**0.43**
29-19	Hazel (Corylus avellana)	Sod carbonate light loam	400		10		50		10		14		67		20		3	
			300	**1.3**	20	**0.5**	1000	**0.05**	30	**0.3**	30	**0.46**	300	**0.2**	10	**2**	10	**0.3**
30-19	Sharp-leaved (Salix acutifolia)	Shallow peat bog	300		4		30		3		3		10		5		3	
			300	**1**	8	**0.5**	500	**0.06**	8	**0.37**	5	**0.6**	80	**0.1**	16	**0.3**	13	**0.3**
31-19	Aspen	Peat bog shallow degraded	500		3		50		4		4		20		10		3	
	(Populus tremula)		400	**1.25**	50	**0.06**	2000	**0.02**	40	**0.1**	20	**0.2**	400	**0.05**	60	**0.1**	60	**0.05**
33-19	Male bugbug (Dryopteris filix-mas)	Sod gley (peat) sandy loam	800		10		80		5		5		10		50		3	
			200	**4**	5	**2**	1000	**0.08**	10	**0.5**	10	**0.5**	100	**0.1**	2	**25**	5	**0.6**
37-19	Male bugbug (Betula pendula)	Turf gley sandy	800		6		45		4		2		35		3		4	
			150	**5.3**	12	**0.5**	1000	**0.04**	11	**0.36**	8	**0.25**	210	**0.16**	10	**0.3**	11	**0.36**
41-19	Yarrow (Achillea millefolium)	Sod carbonate light loam	300		15		10		5		8		29		21		5	
			400	**0.75**	20	**0.75**	1500	**0.006**	30	**0.16**	50	**0.16**	400	**0.07**	40	**0.5**	10	**0.5**
48-19	Hornbeam	Turf podzolic sandy	500		3		40		5		5		40		5		19	
	(Carpinus betulus)		750	**0.6**	7	**0.4**	1000	**0.04**	10	**0.5**	20	**0.25**	200	**0.2**	10	**0.5**	46	**0.4**

mg / kg) and copper (50 mg / kg) was recorded in the Male bugbug (Dryopteris filix-mas), which growing on sod gley (peat) sandy-loamy soils near the village Zhuravychi (site 33-19), concentration of manganese exceeds its background value by 3 times (277 mg/kg). Common bracken (Pterídium aquilínum) (site 17-19) accumulates a significant amount of titanium (3000 mg/kg), lead (30 mg/kg), zinc (100 mg/kg).

Interspecific differences between plants in terms of the content of the above elements are significant. Forest rank (Lathyrus sylvestris) sod-slightly podzolic sandy soils (site 23-19) accumulates titanium, manganese and zinc. A number of plants are characterized by the simultaneous accumulation of several HM, causing high values of reliable pollution. Common hornbeam (Carpinus betulus) sod-podzolized sandy loam soils (site 48-19) is characterized by a simultaneous high content of manganese (500 mg/kg), titanium (40 mg/kg) and lead (18 mg/kg).

Yarrow (Achillea millefolium) sod carbonate light loam soils concentrates nickel (15 mg/kg) and copper (21 mg/kg). Willow sharp-leaved (Salix acutifolia) in peat bogs it is characterized by the minim content of all studied HM, with the exception of manganese.

In a pine tree near the village Yaromel maxim amount of nickel is recorded in samples of lily of the valley (Convallaria majalis). This plant, compared to others, has a higher content of manganese (680 mg/kg) and titanium (89 mg/kg). Sedge shaking (Carex brizoides) alluvial layered sandy soils is released in the presence of copper (20 mg/kg). Very few trace elements are accumulated Scots pine (Pinus sylvestris) (from 0.7 to 4.31 mg/kg).

Titanium accumulat in significant quantities by Hazel common (Corylus avellana) and birch hung (Betula pendula) (48-50 mg/kg) turf gley sandy soils. Its maximal number (except for common) is recorded in samples of raspberries (Rubus idaeus), growing on sod podzolic gley sandy soils, and is 80 mg/kg.

The concentration of copper varies from 2.12 in the male bugbug (Dryopteris filix-mas) to 21.34 mg/kg in yarrow (Achillea millefolium). A lot of copper was found in sedge shaking (Carex brizoides) and raspberry (Rubus idaeus) (up to 20 mg/kg). In general, it can be noted that the copper content in plants of the NNP territory increases with an increase in their biological productivity.

The high accumulation of HM in the aboveground part of the studied plants indicates a significant removal of elements from the soil, which, in turn, makes it possible to consider certain plant species as potential phytoremediators. Another indicator that testifies to the high accumulating capacity of the forest rank (Lathyrus sylvestris), male bugbug (Dryopteris filix-mas), and yarrow (Achillea millefolium) is the prevalence of HM in the aerial part over the root. It should be noted that a high concentration of HM does not have a toxic effect on these plant species, which may indicate their tolerance to anthropogenic pollution.

Conclusions.

Spatially, the landscape-geochemical structure of the NNP and adjacent territories is represented by calcium, calcium-carbonate, carbonate-gley, acid calcium geochemical classes of landscapes.

Analysis of the content of heavy metals in the soils of the territory showed its non-uniform distribution and dependence on the available sources of anthropogenic impact. The highest concentrations of manganese and chromium are found in soils developed on loess deposits, and nickel and copper on glacial deposits.

The first results of studying the microelement composition of the vegetation of the investigated NNP make it possible to conclude that woody and shrub plants of the park territory are characterized by an increased content of manganese, titanium, copper and lead in comparison with similar species of plants that are common in other parts of the Polissia region. Within each phytocenosis there are plants-concentrators of a certain element. In particular, plants with high ability to accumulate HM belong: common bracken (Pterídium aquilínum), raspberries (Rubus idaeus) and forest rank (Lathyrus sylvestris). The supply of elements in phytocenoses depends on the chemical composition of plants, their total biomass, which is determined by the mineral composition and soil moisture conditions.

The main direction of further research should be further study of the distribution of macroelements and microelements in different genetic types of soils; establishment of the reference content of elements in geochemical landscapes to establish the intensity of migration and the nature of the distribution of elements; determination of pathological and specific plant diseases due to the geochemical features of the landscape.

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The impact of aeration on ecological state of lake Telbyn in Kyiv

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Abstract. Lake Telbyn is considered to be one of the largest lakes located in the eastern part of Kyiv. The artificial aeration of this lake was started at the end of 2016 by using of 8 aerators, which has been continuing so far. The main perpose of this measure is improving the ecological state of the lake mostly for recreational use. There were carried out a field study of the lake and the analysis of remote sensing data. Physical and chemical characteristics of water, phytoplankton biomass, chlorophyll *a* concentration and some other parameters at the different depths were studied. It was found out that artificial aeration has a positive effect on the ecological state of the lake. The water aeration causes the blur of thermocline whereas the impact on its depth is not essential. Under impact of aeration the concentration of dissolved oxygen become larger, mostly in the bottom layer. The highest concentration of ammonium nitrogen in a warm period is observed in the bottom layer of the lake. The deep location of aerators causes the increasing of concentration in bottom layer. At the same time there is not visible impact on concentration near the surface. The similar result was obtained for the concentration of inorganic phosphorus. The impact of aeration on algal bloom is not such essential as on hydrochemical characteristics. The artificial aeration causes negative impact on the phytoplankton abundance and less effect on their biomass. It means the larger effect on the algae with small cells. In other words the aeration has larger impact on green algae than on blue-green ones. The use of remote sensing data showed that ecological state of Lake Telbyn during the aeration period improved comparably with other lakes of Kyiv. As a result of aeration, the view of water surface of the lake became more similar to water surface of the Dnipro River, which flows through the city.

Keywords: aeration, lake, thermocline, nutrients, phytoplankton, remote sensing data

Вплив аерації на екологічний стан озера Тельбин у Києві

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Анотація. Озеро Тельбин вважається одним із найбільших озер, розташованих у східній частині Києва. Наприкінці 2016 р. було розпочато штучну аерацію цього озера за допомогою 8 аераторів, що триває і досі. Основна мета цього заходу – поліпшення екологічного стану озера – передусім для рекреаційного використання. Виконано польові дослідження озера та аналіз даних дистанційного зондування Землі. Вивчено фізико-хімічні характеристики води, біомасу фітопланктону, концентрацію хлорофілу та деякі інші параметри на різних глибинах. З'ясовано, що штучна аерація позитивно впливає на екологічний стан озера. Аерація води зумовлює розмивання термокліну, водночас її вплив на його глибину неістотний. Під впливом аерації концентрація розчиненого кисню стає більшою, насамперед у придонному шарі. У теплий період року найвища концентрація азоту амонійного спостерігається у придонному шарі озера. Глибоке розташування аераторів зумовлює підвищення концентрації в нижньому шарі. При цьому не спостерігається видимого впливу на концентрацію біля поверхні. Аналогічний результат отримано щодо концентрації неорганічного фосфору. Вплив аерації на "цвітіння" водоростей не настільки значний, як на гідрохімічні характеристики. Штучна аерація спричиняє негативний вплив на кількість фітопланктону та менший вплив на їх біомасу. Це означає більший вплив на водорості з дрібними клітинами. Іншими словами, аерація має більший вплив на зелені водорості, ніж на синьо-зелені. Використання даних дистанційного зондування показало, що екологічний стан озера Тельбин за період аерації покращився, порівняно з іншими озерами Києва. Внаслідок аерації вигляд водної поверхні озера наблизився до вигляду водної поверхні Дніпра, що тече через місто.

Ключові слова: аерація, озеро, термоклін, біогени, фітопланктон, дані дистанційного зондування Землі

Introduction.

Artificial aeration of water bodies is a well-known and widespread method aimed at improving their ecological state. Accordingly, there is a significant amount of scientific works (Ashley 1983, Beutel, Horne 1999, Gasi et al 2009, Heo, Bomchul 2004, Imteaz, Asaeda 2000, Osuch, Podsiadłowski 2012, Riabov, Sirenko 1982) devoted to this activity. In Ukraine, such measures are also carried out, but mainly in small water bodies and in order to improve the living conditions of fish. Until recently, the aeration of rather large lakes to improve their ecological state for recreational purposes was not performed. It was first started on Lake Telbyn (sometimes Telbin), which is located in Kyiv.

The Lake Telbyn is located in the eastern part of the city. Its geographical coordinanes are: 50°25'33" N, 30°36'10" E. The lake originates from the old channel of the Dnipro River and by the mid of the 19th century it had been much larger than it is now. In 1868–1869 it was divided by the railway on two parts. The northern part known nowadays as the Lake Telbyn was gradually built up around. The southern part during the next decades was transformed to the Lake Koroliok. The hydraulic connection of these lakes with other water bodies is almost absent.

The current area of the Lake Telbyn is 13.6 hectares, perimeter is 2.1 km and the maximum depth is 13 m. There are two beach areas that are rather popular with the local people for recreation.

Besides the Lake Telbyn there are many other water bodies in the eastern part of Kyiv. Some data as to these objects, obtained from satellites images, were used for the study as well (fig. 1).

Fig. 1. Water bodies of Kyiv under study: 1– Lake Telbyn, 2 – Lake Almazne, 3 – Lake Koroliok, 4 – Lake Soniachne, 5 – Berkivshchyna bay, 6 – Lake Lebedyne, 7 – Lake Tiagle

The air for the aeration purpose is supplied by a compressor to 8 aerators, which were installed uniformly on the Lake Telbyn at the end of 2016. The total productivity of the aerators makes 360 m^3 per an hour, but at the beginning of aeration it was much less – about 100 m^3 per hour. Actually the operation of the aerators was irregular. At first the depth of aerator installation was rather small – 1.5–2.5 m from the water surface. Gradually some aerators were moved from small deptht deeper – up to 5 m (fig. 2).

The study of the ecological state of the Lake Telbyn was started in early 2000s (Morozova, 2008; Morozova, 2009). It was defined the anaerobic conditions in the bottom layer of the lake, mainly during the warmest period. It was found out great differences in the concentration of inorganic phosphorus and total iron in the surface and bottom layers – up to 20 times.

According to the results of hydrochemical study carried out in 2007–2008, the Lake Telbyn was exposed to eutrophication. The pH values varied within 6.75–9.40, the concentration of dissolved oxygen amounted to 0.0–16.5 mg/dm^3, ammonium nitrogen – 0.32–13.9 mg/dm^3, total iron – 0–2.65 mg/dm^3. When having the direct temperature stratification it was recorded the essential increase in ammonia nitrogen and iron concentrations in the bottom layer and the deficit of dissolved oxygen at the same time. The high concentration of suspended solids in the surface layer, which reached 80 mg/dm^3, indicated an intense algal bloom (Morozova, 2008; Morozova, 2009).

The study, carried out by authors of this article in the warm period of 2009, revealed the existence of thermocline at the depth of about 3 m.

It is possible to evaluate the ecological state of this waterbody using phytoplankton data, which was successfully proven in previous works (Bilous et al., 2014; Bilous et al., 2016). In turn, there were some studies on the ecological state of the water bodies located within the urban area of Kyiv, based on remote sensing data (Vyshnevskyi and Shevchuk, 2018). It was obtained a rather close correlation in warm period between the water transparency, measured with

Fig. 2. Satellite image of the Lake Telbyn with the location of installed aerators

Secchi Disk, and the values of the spectral band B3 of the Landsat 8 satellite, which correspond to green colour. The stronger correlation between the water transparency and the satellite data was obtained for the expression SD = (B4–B2)/B3.

Materials and methods.

The current investigation of the ecological state of the Lake Telbyn, regarding the impact of artificial aeration, included field study and analysis of remote sensing data.

The field study was carried out during warm period of 2017–2018 with the focus on hydrochemical measurements and characteristics of phytoplankton. The most complete study, including samplings of phytoplankton, was carried out 06.07.2017, 02.08.2017, 08.08.2017, 13.09.2017, 10.07.2018, 09.08.2018, 16.08.2018 and 30.08.2018. Some additional measurements on hydrochemical characteristics were carried out on 24.07.2018, 21.11.2018 and 11.03.2020 as well. The study was carried out in the different parts of the lake with various conditions: very close and far away from the working aerators and also near aerators installed at different depths.

The following hydrochemical characteristics were studied: water temperature, concentration of dissolved oxygen, mineralization, nitrogen compounds, inorganic phosphorus and pH. The concentration of dissolved oxygen, mineralization, pH were determined using the multifunctional device AZ-86031. The concentration of dissolved oxygen was determined by Winkler's method as well. Water clarity was measured by use of the Secchi Disk with diameter of 30 cm. The water clarity was measured in the Dnipro River in the point closed to the Lake Telbyn as well. Seignette salt with Nessler's reagent was used to determinate ammonium nitrogen ($N\text{-}NH_4^+$), the Grisse reagent – to determine nitrite ions ($N\text{-}NO_2^-$), sodium salicylate for nitrate ions ($N\text{-}NO_3^-$), and ammonium molybdate with ascorbic acid for dissolved inorganic phosphorus ($P\text{-}PO_4^{3-}$) or soluble reactive phosphorus (SRP) (Nabivanets et al., 2007).

The algological samples in alive state were investigated using Zeiss and PZO microscopes under magnification × 400–1000. The quantitative analys of plankton was carried out using a Nageotte Chamber (0.2 cm^3). No less than 800 cells from each sample were calculated. The biomass of phytoplankton was determinated by studied cells in particular volume of water. Dominant species were considered those, the share of which exceeded 10 % of the total biomass.

For the identification of the taxonomic algae species the following sources were used: Süsswasserflora … (1998, 2005, 2013), Asaul (1975), Tsarenko (1990), Lange-Bertalot et al. (2017). The taxonomic system of algae, accepted in the monograph series Algae… (2006, 2009, 2011, 2014) and nomenclature changes to Algae Base (Gury and Gury, 2020) were determined on the base of common system derived from T. Cavalier-Smith (2004).

The concentration of chlorophyll *a* in phytoplankton was determined using the standard spectrophotometry method and calculated using Jeffrey and Humphrey equation (Jeffrey and Humphrey, 1975).

The search of high-quality satellite images was the first stage in the study of the Lake Telbyn using the remote sensing data. It is focused on the data of the Landsat 8 satellite. Data processing of satellite images was carried out using the ArcMap 10 program. The obtained data were analyzed along with making images in pseudo-natural colours and using some indices, which were the ratio of satellite images spectral bands. The study was carried out for the Lake Telbyn and some other water bodies located nearby. The values of the bands B2, B3 and B4 in some points of their water area were measured. The average values were used for further comparison. In total, 14 images of the Landsat 8 satellite, obtained in a warm period during 2014–2020, were used in the research process: 6 – in 2014–2016 and 8 – in 2017–2020. The last processed image was obtained on 16.08.2020.

Results and Discussion.

Hydrometeoriological conditions

During the some last years, the air temperature in Kyiv, likewise over the world, was warmer than ussual. According to the observations of a local meteorological station in Kyiv the unnual air temperature in 2016–2020 was two or even more degrees higher compared to the period of 1961–1990 (table 1).

Table 1. Mean monthly air temperature (°C) at the meteorological station in Kyiv

Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Mean
2016	-5.7	2.0	3.9	12.4	15.5	20.6	22.4	21.1	16.1	6.5	1.2	-1.5	9.5
2017	-4.9	-2.8	6.2	10.4	15.3	20.0	20.9	22.4	16.4	8.4	3.3	1.6	9.8
2018	-2.4	-3.8	-1.9	13.1	18.8	20.6	21.4	22.5	17.3	10.7	0.3	-2.2	9.5
2019	-4.5	0.6	5.1	10.6	17.0	23.6	19.8	20.7	15.9	11.1	4.6	2.7	10.6
2020	0.8	2.5	6.5	9.9	12.4	21.7	21.9	21.4	18.4	12.5	2.1	3.8	10.9
Norm	-5.6	-4.2	0.7	8.7	15.2	18.2	19.3	18.6	13.9	8.1	2.1	-2.3	7.7

Under these circumstances, the ecological state of the Lake Telbyn, even having artificial aeration, can be worse than in the years with lower water temperature. Hydrometeorological conditions before and during the field studies play the important role as well.

Due to the evaporation of water from the surface of the lake (especially in the warm period) its level was decreasing. Thus, from 04.05.2018 until 21.11.2018 it decreased by 35 cm.

Water clarity

The water clarity in the Lake Telbyn was measured in 2018 using the Secchi Disk with the intervals of about 10 days. The lowest water clarity was observed in the beginning of August (table 2).

The water clarity in the Dnipro River at this time was much larger. During 2018 it was as follows: 10.07 – 151 cm, 22.07 – 153 cm, 09.08 – 131 cm, 16.08 – 156 cm, 28.08 – 143 cm.

Water temperature

The water temperature was permanently recorded during the field studyes. On all dates of measurements, except 21.11.2018 and 11.03.2020, a thermocline phenomen occurred. In the summer period of 2017 it was observed at the depth of 5–5.5 m, in summer of 2018 it was about 6 m.

The carried out study proves the positive impact of aeration on the distribution of water temperature. Distribution of water temperature near the working aerators by depth was more even comparably with the cases without aeration (fig. 3).

It is important to note that the change of the depth of aerator does not influence on the depth of thermocline, but aerator, which is installed deeper, causes more visible blurring of the thermocline.

Concentration of dissolved oxygen

The concentration of dissolved oxygen significantly depends on the season. In summer period under the effect of algal bloom the highest concentration of dissolved oxygen is observed in the surface layer. In some cases the oxygen saturation exceedes 100 % and reaches 150–155 %. First of all, it should be noted that the changes in the concentration of dissolved oxygen in depth in the area with aeration are more uniform than in the area without aeration. It is very important the positive impact of aeration on the concentration in the bottom layer. Thus, on July 10, 2018, in the zone with aeration it was 2.9, and in the zone without aeration – only 1.1 mg/dm^3 (fig. 4).

Table 2. Water clarity (cm) of the Lake Telbyn during 2018

04.05	17.05	29.05	09.06	20.06	10.07	22.07	09.08	16.08	28.08	21.11
74	70	75	75	74	54	54	49	61	62	165

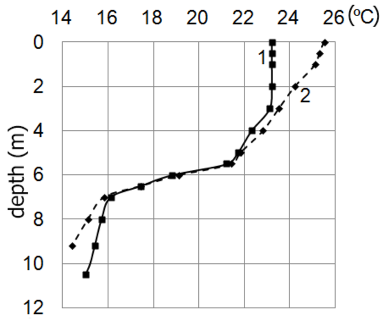


Fig. 3. Distribution of water temperature by depth in the Lake Telbyn on 10.07.2018:
1 – close to the aerator No 3 installed at the depth of 1.5 m, 2 – without aeration near unoperated aerator No 7

The increasing of the depth of aeratots causes the increasing of dissolved oxygen concentration in the bottom layer.

In the last summer days and in September the concentration of dissolved oxygen in the surface layer becomes less. This time the maximum values of dissolved oxygen are observed at the depth of several meters. In the spring, in particular on 11.03.2020, the concentration of dissolved oxygen in the surface and bottom layers was almost the same – 9.5–10.3 mg/dm^3, the saturation level was 78.5–87.2 %.

Water mineralization

In general, the Lake Telbyn is characterized by rather small mineralization. To some extent, it depends on the season: the smallest values are observed in the spring period while in autumn mineralization becames higher. The highest values (353–355 mg/dm^3) were observed on 21.11.2018.

Water pH

The water pH in a whole corresponds to the concentration of dissolved oxygen distribution by depth and to some extent to the distribution of phytoplankton. The highest value (up to 8.5–9.0) in warm period was observed near water surface. In March 2020 the pH of the water was 8.2–8.3. The noticeable effect of aeration on the water pH was not recorded.

Concentration of nutrients

The concentration of ammonium nitrogen, nitrate ions and inorganic phosphorus were the key points of field study.

The concentration of ammonium nitrogen in the warm period greatly changes by depth: in the surface layer it is significantly less than near the bottom. The largest changes in the ammonium nitrogen concentration correspond to the depth of thermocline. In the summer of 2017 the largest changes in ammonium nitrogen were observed at a depth of 5–5.5 m. On 13.09.2017, the zone of the largest changes moved a little deeper at the depth of about 6 m. In 2018, the largest changes of ammonium nitrogen concentration were observed at the same depth of about 6 m.

The aerators, installed at a rather small depth, do not have any essential effect on NH_4^+ ions distribution. The increasing the depth of aerators causes the rise of NH_4^+ concentration in the bottom layer (fig. 5).

The concentration of nitrite nitrogen by depth and water area is approximately the same. In different periods it was 0.004–0.035 mg N/dm^3. The effect of aeration on this chemical compound is not essential.

The concentration of nitrate nitrogen by depth is generally the opposite of the concentration of ammonium nitrogen. The highest concentration (0.8–1.0

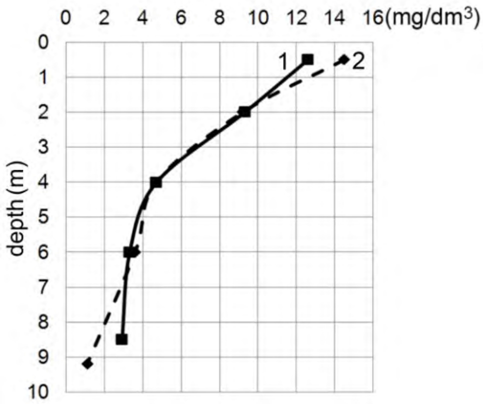


Fig. 4. The concentration of dissolved oxygen by depth in the Lake Telbyn on 10.07.2018:
1 – close to the aerator № 3 installed at a depth of 1.5 m, 2 – without aeration close to the unoperated aerator No 7

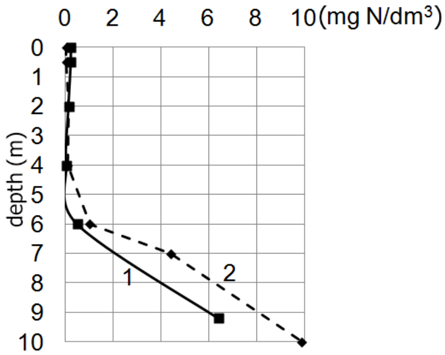


Fig. 5. Concentration of ammonium nitrogen by depth in Lake Telbyn on 16.08.2018:
1 – close to the aerator № 4 installed at the depth of 1.5 m, 2 – close to the aerator № 5 installed at the depth of 5 m

mgN/dm^3) in warm period is observed in the surface water layer. In March 2020 the distribution of all forms of nitrogen by depth was approximately equal.

The concentration of inorganic phosphorus by depth is distributed similarly to NH_4^+ concentration. The largest concentrations are recorded in the bottom layer. The increasing of the depth of installed aerators causes a rather small rise of inorganic phosphorus concentration in the bottom layer. The effect of aeration on the surface layer is absent (fig. 6).

In our opinion, the aeration of the lake should be performed carefully, because the rise of water from the bottom layer, which is rich in nutrients, can cause an increase their concentration near the surface and the corresponding growth of phytoplankton under favorable conditions. About negative effects of aeration are mentioned in (Gafsi et al 2009).

Phytoplankton

There were five stages of the investigation on phytoplankton in the Lake Telbyn during 2017–2018: threefold in 2017 (06.07, 02.08 and 13.09) and twice in 2018 (10.07 and 16.08).

On 06.07.2017, the abundance of cells in the surface layer was 10–13 × 10^6 per dm^3, in water layer it was 11–19 × 10^6 per dm^3 and at the bottom 5–8 × 10^6 per dm^3. Correspondingly, the biomass of phytoplankton was the folloiving: in the surface layer – 2–5 mg/dm^3, in water layer – 5–8 mg/dm^3, at the bottom – 1.5–2.9 mg/dm^3.

On 02.08.2017, the quantitative characteristics of phytoplankton were almost the same as in previous measurements. In surface layer, the abundance was 14–16 × 10^6 cells/dm^3, in water layer it was 10–11 × 10^6 cells/dm^3 and at the bottom – 9–15 × 10^6 cells/dm^3. The biomass in the surface layer was 4–5 mg/dm^3, in water layer it was about 4 mg/dm^3 and at the bottom – 3–5 mg/dm^3.

On 13.09.2017, the number of cells in the surface layer was 10–13 × 10^6 cells/dm^3, in water layer 7–8 × 10^6 cells/dm^3 and at the bottom about 6 × 10^6 cells/dm^3. The biomass of phytoplankton in the surface and water layer was about 1 mg/dm^3 and at the bottom – 0.7–0.8 mg/dm^3.

In 2018, phytoplankton samples were taken in the zones with essentially different conditions as to water aeration. On 10.07.2018, one area close to the working aerators and another area without aeration were investigated. In the second case (16.08.2018) one sampling point was located near working aerator, installed at the small depth, and another one was located close to the aerator, installed at the depth of 5 m.

On 10.07.2018, the abundance of phytoplankton in the zone without aeration reached 35 × 10^6 cells/dm^3, simultaneously in the aeration zone it was less

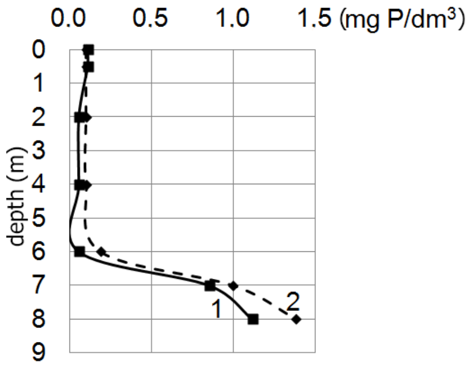


Fig. 6. Concentration of inorganic phosphorus by depth in the Lake Telbyn on 30.08.2018:
1 – close to the aerator No 4 at the depth of 1.5 m, 2 – close to the aerator No 7 installed at the depth of 4 m

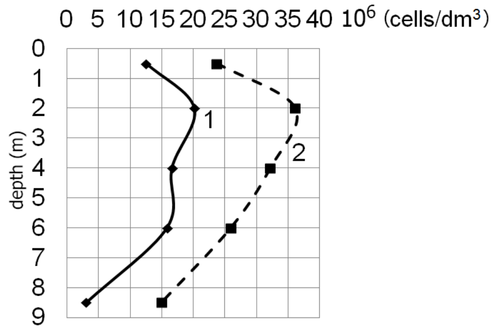


Fig. 7. The distribution of abundance by depth in the Lake Telbyn on 10.07.2018:
1 – close to the aerator No 3 installed at the depth of 1.5 m, 2 – in zone without aeration near unoperated aerator No 7

almost twice. In both cases the largest abundance was recorded at the depth of about 2 m (fig. 7).

As it can be seen on the fig. 7, the abundance of phytoplankton in the zone with aeration is significantly less than in the zone without it. At the same time the difference in biomass of phytoplankton along the water column is not so essential. It can be explained by the effect of aeration mostly on small-sized species. The similar results were obtained in (Ashley, Nordin 1999, Beutel, Horne 2009) and othe researhes.

The largest abundance of phytoplankton was recorded on 16.08.2018. In the 2 m layer from the surface it reached 75–80 × 10^6 per dm^3. At the same time the zone of maximum biomass was observed at the depth of 2–4 m. The largest biomass (about 34 mg/dm^3) was recorded in this depth in the zone close to the aerator, installed near surface.

The share of blue-green algae (Cyanoprokaryota) on 06.07.2017 was 71 % and for green algae 24 %. In three weeks (on 02.08.2017) the value changed somewhat, the share of blue-green increased to 77 % and green algae decreased to 17 %. On 13.09.2017, the share of blue-green algae reached 79 % and green one decreased to 15 %. As can be seen, during June–September 2017, the share of blue-green algae increased and green algae decreased.

In 2018, the study was carried out in the zones with different conditions of aeration. On 10.07.2018, in the zone with aeration the share of blue-green algae in total by depth equalled 91 %, whereas without aeration 94 %. A more noticeable difference was obtained for the abundance of green algae. In the first case, its share was 7.7 %, in another 5.5 %. It can be added that in surface layer the difference in abundance of green algae was larger: in the zone with aeration it was 10.5 % whereas without aeration 6.0 %.

On 16.08.2018, the share of blue-green algae abundance in the zone with aerator on small depth was 97 % and in the zone with the aerator on the depth 5 m 94 %. Accordingly, the share of green algae equalled 2 % and 4 %.

In the first year of aeration, on 06.07.2017 the dominant complex of blue-green algae (Cyanoprokaryota) representatives was the following: *Dolichospermum flosaquae* (Lyngb.) Wacklin, Hoffmann et Komarek, *Aphanizomenon flosaquae* (L.) Ralfs ex Bornet et Flahault, *Anagnostidinema amphibium* (C. Agardh ex Gomont) Strunecký, Bohunická, J.R. Johansen et al., *Oscillatoria tenuis* J. Agardh ex Gomont, as for green algae it should be mentioned *Acutodesmus pectinatus* (Meyen) P. Tsarenko. On 02.08.2017, the dominant species from this group's representatives were the following: *Anagnostidinema amphibium*, *Dolichospermum flosaquae* and *Spirulina subtilissima* Kütz. ex Gomont observed in all depths. On 13.09.2017, the dominant complex was formed by blue-green algae *Aphanizomenon flosaquae*, *Spirulina subtilissima*, *Merismopedia tranquilla* (Ehrenberg) Trevisan (=*Merismopedia punctata* Meyen) and *Anagnostidinema amphibium*. The abundance of phytoplankton was in the range of 1–8 × 10^6 cells per dm^3 and the biomass varied from less than 1 to 4 mg/dm^3.

In the year 2018 the dominant complex of species changed somewhat. On 10.07.2018, the dominant species from Cyanoprokaryota representatives were the following: *Aphanizomenon flosaquae* and *Anagnostidinema amphibium*. Its abundance varied from 3 to 11 × 10^6 cells per dm^3. The dominant species regarding biomas was presented by *Ceratium hirundinella* (O.F. Müller) Dujardin, with the values from 1.8 to 4.23 mg/dm^3. On 16.08.2018, abundance was presented mostly by *Anagnostidinema amphibium* and *Merismopedia warmingiana* (Lagerheim). Their abundance had the range of 9.5 to 75 × 10^6 cells per dm^3. The biomas at this period was presented mostly by *Ceratium hirundinella* and *Parvodinium umbonatum* (F. Stein) Carty with values varied from 1.4 to 23.8 mg/dm^3.

Concentration of chlorophyll a

There were 5 measurements of chlorophyll *a* concentration on the Lake Telbyn during 2017–2018: threefold in 2017 (06.07, 02.08 and 13.09) and twice in 2018 (10.07 and 16.08). The concentration of chlorophyll *a* on 06.07.2017 varied from 60 ug/dm^3 at the depth 0.5–4 m to 25–30 ug/dm^3 at depth 6–9 m. On 02.08.2017, the concentration of chlorophyll *a* somewhat increased: 80–85 ug/dm^3 in surface layer, 100–105 at the depth of 2 m, 60–67 at the depth of 4 m and 45–46 ug at the bottom. The highest values were observed on 13.09.2017: 188–218 ug/dm^3 in surface layer, 103–107 ug/dm^3 at the depth of 4 m and 45–50 ug/dm^3 near the bottom. Such larger values than in previous cases may be explained by the known fact, that concentration of chlorophyll *a* depends on not only on the abundance of algae but also on the consentration of nutrients and water temperature as well (Kureyshevich et al., 2016). The high temperature has negative impact on biosynthesis of algae. As the result, inspite less abundance of algae, the concentration of chlorophyll *a* on 13.09.2017 was larger than in summer.

The concentration of chlorophyll *a* in 2018 was similar to the previous year. The aeration makes the concentration of chlorophyll *a* by depth more uniform. The highest concentration becomes less (Fig. 8).

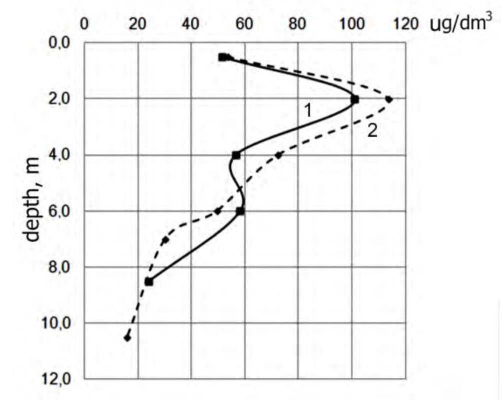


Fig. 8. Vertical distribution of chlorophyll *a* concentration in the Lake Telbyn on 16.08.2018:
1 – close to the aerator No 4 installed at the depth of 1.5 m, 2 – close to the aerator No 5 installed at the depth of 5 m

In general, the effect of aeration on the concentration of chlorophyll *a* is relatively small. A similar result was obtained in (Ashley, Nordin 1999).

Remote sensing data

The carried out field studies showed the large differences in water quality from one measurement to another. It can be explained by the impact of seasonal features and hydrometeoriological factors. Under these circumstances, it is hard to identify the impact of artificial aeration among other influencing factors. For this purpose, the remote sensing data were used. The main idea was to compare the ecological state of Lake Telbyn with other water bodies before and under the impact of aeration. Accordingly, it was treated data before aeration, i.e. in 2014–2016 and with aeration in 2017–2020 (Fig. 9).

It is evident from the image obtained on 29.07.2016, that the colour of water in the Lake Telbyn essentially differs from the colour of water in the Dnipro River and it is close to the water colour in the neighbouring lakes. In the second case, namely, on 04.08.2018, the water colour of the Lake Telbyn became almost the same as in the Dnipro River. A similar result was obtained for other images of 2019–2020.

These differences become more evident in case of use images in larger scale and created on the base of NDTI index, which is the ratio: NDTI = (B4 – B3) / (B4 + B3). By this ratio the band B3 corresponds to the green colour of the spectrum, B4 – to the red one (fig. 10).

The comparison of optical images has an element of subjectivity. Therefore, the ecological state of water bodies was analyzed on the base of digital values of the B3 band of the Landsat 8 satellite. The meaning of B3 depends on phytoplankton abundance: larger quantity corresponds to the larger B3 and vice versa. In particular, it concerns the blue-green and green algae which dominate in warm period. There is an opposite correlation between water clarity and B3 as well (Vyshnevskyi, Shevchuk 2018).

During the year, the greatest value of the B3 of the Landsat 8 satellite is observed in the period with the largest algal abundance – usually in August when the water clarity is the lowest. Thus, according to the data of the B3 band it is possible to estimate not only water transparency of lakes but their ecological state as well. The same it is concerned for lakes located nearby: Almazne, Koroliok, Lebedyne, Soniachne, Tiagle and Berkivshchyna bay (see the fig. 1).

For this aim it were analyzed 14 satellite images, from which 6 ones were obtained for 2014–2016 and

a *b*

Fig. 9. The satellite images of the south-eastern part of Kyiv in pseudo-natural colours: *a* – on 29.07.2016, *b* – on 04.08.2018

8 ones for 2017–2020. Before the start of aeration the Lake Telbyn had the average position with value of B3 among other water bodies. Under impact of aeration, the position of the lake in 2017–2020 by the B3 value was essentially improved. It took the second position after Berkivshchyna bay which belongs to the Dnipro River (the fig. 11).

The same result was obtained for the ratio (B3–B2) / (B3+B2). As in previous case this ratio for the Lake Telbyn in 2017–2020 became the lowest except for the Berkivshchyna bay (fig. 12).

The essential growth of the ratio (b2–B4) / B3 in the Lake Telbyn during aeration period was observed as well. Thus, it means the larger decreasing of the B3 value comparably with the other spectral bands.

Conclusion.

The Lake Telbyn is the first rather large lake in Ukraine, for which the artificial aeration of water was started to improve its ecological state mostly for recreational use. For this aim 8 aerators with air supply from the compressor were installed at the end of 2016.

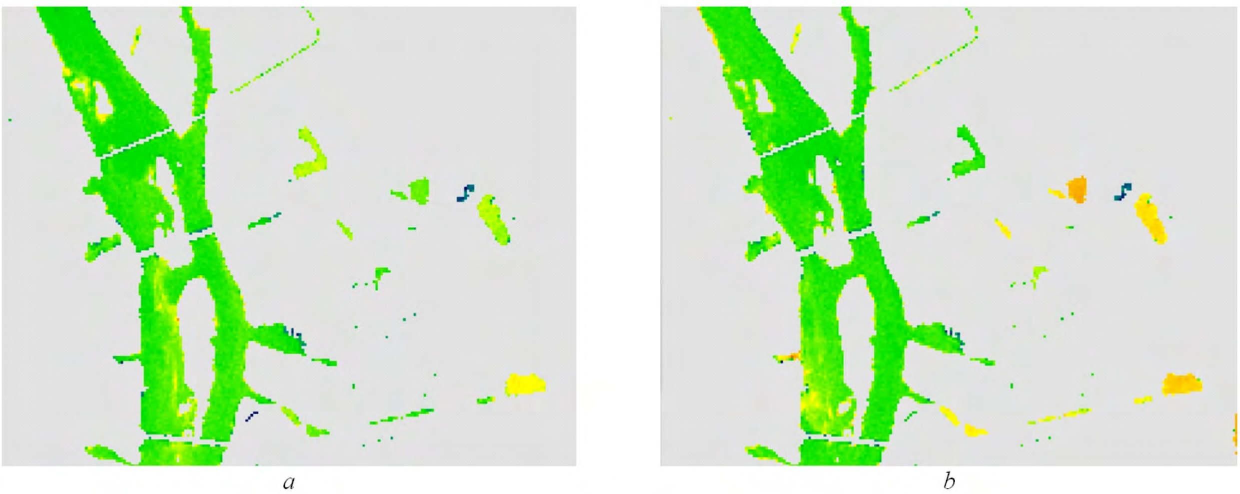
The water aeration causes the blur of thermocline whereas the impact on its depth is not essential.

The concentration of dissolved oxygen by depth mostly depends on algal bloom and the water temperature. The highest value is observed in surface layer when the algal bloom is the highest.

The operation of aerators causes a slight decrease in the concentration of dissolved oxygen in the surface layer and an increase in concentrations in the bottom layer. In the end of summer period the depth of zone with the highest concentration of dissolved oxygen goes down. This time the impact of aeration is rather small.

The impact of aeration on pH parameter is not essential. There is direct correlation of this parameter with the distribution by depth of dissolved oxygen.

The highest concentration of ammonium nitrogen in warm period is observed in the bottom layer. The deep location of aerators causes the increasing of concentration in bottom layer. At the same time there



a *b*

Fig. 10. The images of the Lake Telbyn and adjacent water bodies created on the base of the NDTI index: *a* – on 29.07.2016, *b* – on 04.08.2018

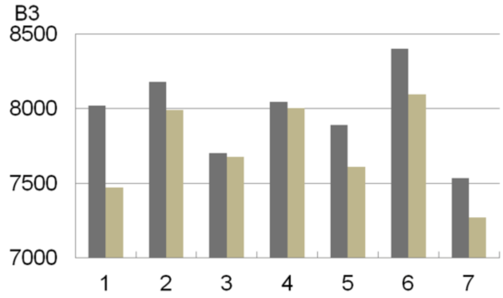


Fig. 11. The B3 valueof the Landsat 8 satellite for some water bodies of Kyiv during warm period:

1– the Lake Telbyn, 2 – the Lake Almazne, 3 – the Lake Koroliok, 4 – the Lake Lebedyne, 5 – the Lake Soniachne, 6 – the Lake Tiagle, 7 – the Berkivshchyna bay (left columns correspond to 2014–2016, right columns – to 2017–2020)

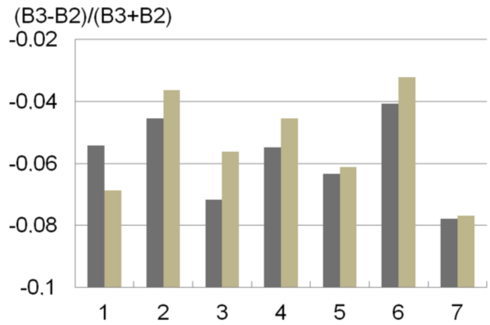


Fig. 12. The value of (B3–B2) / (B3+B2) the Landsat 8 satellite for some water bodies of Kyiv during warm period:

1– the Lake Telbyn, 2 – the Lake Almazne, 3 – the Lake Koroliok, 4 – the Lake Lebedyne, 5 – the Lake Soniachne, 6 – the Lake Tiagle, 7 – the Berkivshchyna bay (left columns – 2014–2016, right columns – 2017–2020)

is not visible impact on concentration near the surface. The similar result was obtained for the concentration of inorganic phosphorus.

The impact of aeration on phytoplankton biomass as well as on its composition is not such essential as on hydrochemical characteristics. The artificial aeration causes negative impact on the phytoplankton abundance and less effect on their biomass. It means the larger effect on the algae with small cells. In other words the aeration has larger impact on green algae than on blue-green algae. The water aeration has some impact on the vertical distribution of chlorophyll *a* concentration. In the zone with aeration its concentration is somewhat less than without aeration.

Comparison of the ecological state of the Lake Telbyn with other lakes, carried out on the base of satellite data, showed a positive effect of aeration. Nowadays, the color of water surface of the lake has become closer to the Dnipro River than it was before aeration.

In general, there is positive effect of aeration on the ecological state of the Lake Telbyn.

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Social and affordable housing in Ukraine: mechanism and practices of provision

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Abstract. The purpose of this publication is to research the state and mechanisms of formation of social and affordable housing in Ukraine and to determine the basic scientific and practical principles of improving housing. The study examines the theory and practice of providing housing for citizens in Ukraine. The concepts of “free”, “social” and “affordable” housing are studied and the practice of mechanisms of their formation in European countries is given. The legislative base of formation of social and affordable housing in Ukraine is briefly described. The general level of demand for housing in our state is outlined. To study the level of housing affordability for the population of our country, the authors used the adapted UN HABITAT methodology, taking into account the Ukrainian realities. We have taken as a basis a young family with two working people with average incomes for the region minus expenses at the subsistence level. At the same time such a young family have mostly one or two children and the priority of their purchase will be a small one-two-room apartment (or a two-bedroom apartment with a modern approach to construction) with an area of 43 sq.m. The results of the assessment of housing affordability obtained in this way show a general tendency to increase in the housing affordability index in Ukraine. At the same time, the real indicators of affordability are still quite low and characterize a fairly long period of cash savings of the population to obtain housing. The average value of affordability is 9.2 years in 2019, which is almost 6 times higher than the indicators of 2007. The value of affordability in the state varies considerably. It is found that the cities of Kyiv, Zaporizhia, Dnipropetrovsk, Kyiv and Sumy regions have the highest affordability indicators. The lowest values are typical for the Western region of the state, in particular Zakarpattia, Chernivtsi, Ternopil, Lviv, Rivne and Volyn regions. They are in the range of 11.5-16 years, which is almost 4 times different from the best indicators. The connection between housing affordability and the volume of construction and its commissioning and GDP growth rates is estimated. The state of mortgage lending in the state is analyzed. It has been found that there are currently more than 20 programs to support citizens in purchasing housing in Ukraine, but the effectiveness of most such programs is questionable and requires state support. Ways to implement an effective housing policy and its main components are proposed.

Key words: social housing, affordable housing, demand for housing, housing construction, mortgage lending, housing programs, housing policy

Соціальне і доступне житло в Україні: механізм та практика забезпечення

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Анотація. Метою даної публікації є дослідження стану і механізмів формування соціального й доступного житла в Україні та визначення основних наукових та практичних засад вдосконалення житлового забезпечення. В дослідженні розглянуто теорію і практику житлового забезпечення громадян в Україні. Досліджено поняття «безкоштовного», «соціального» і «доступного» житла та приведена практика механізмів їх формування в країнах Європи. Коротко охарактеризовано законодавчу базу становлення в Україні соціального та доступного житла. Окреслено загальний рівень попиту на житло в нашій державі. Для дослідження рівня доступності житла для населення нашої держави авторами застосована адаптована методика ООН ХАБІТАТ з урахуванням українських реалій. За основу взята молода сім’я, в якій є двоє працюючих людей з середніми для регіону доходами мінус витратами на рівні прожиткового мінімуму. При цьому така молода сім’я матиме здебільшого одну чи дві дитини і в пріоритеті їх купівлі буде невелика одно-двокімнатна квартина (або ж двоспальна квартира за сучасним підходом до будівництва) площею 43 м.кв. Отримані в такий спосіб результати оцінки доступності житла показують загальну тенденцію до зростання індексу доступності житла в Україні. В той же час реальні показники доступності є ще достатньо низькими та характеризують досить довгий період грошових накопичень населенням для отримання житла. Середнє значення доступності складає 9,2 роки в 2019 році, що майже в 6 разів вище показників 2007 року. Значення доступності в державі досить суттєво варіюється. З’ясовано, що найвищі показники доступності мають місто Київ, Запорізька, Дніпропетровська, Київська та Сумська області. Найнижчі значення властиві для Західного регіону держави, зокрема Закарпатської, Чернівецької, Тернопільської, Львівської, Рівненської та Волинської областей. Вони знаходяться в межах 11,5-16 років, що в майже 4 рази їх відрізняє від кращих показників. Оцінено зв'язок доступності житла з обсягами будівництва й прийняття його в експлуатацію та темпами зростання ВВП. Проаналізовано стан іпотечного кредитування житла в державі. З'ясовано, що в Україні на разі існує більш як 20 програм підтримки громадян при придбанні житла, проте ефективність більшості таких програм сумнівна та потребує державної підтримки. Запропоновано шляхи реалізації ефективної житлової політики та її основних складових.

Ключові слова: соціальне житло, доступне житло, попит на житло, житлове будівництво, іпотечне кредитування, житлові програми, житлова політика

Introduction.

The issue of housing is a complex and interesting aspect of the research. This problem is extremely relevant for social geography, because the impact of the territory on housing is undeniable, and the housing cost and the attractiveness of its construction is determined by socio-geographical factors, including location and affordability, comfort and neighborhood, functionality and quality. The last two components are the basis of construction cost price, while the others are just price components and significant surcharges to it. Big cities of the state are the centers of attraction for residents of the periphery and that is why the cities' housing potential makes it possible for such centers to be realized and attract inhabitants.

The issues of housing affordability for the population, providing housing for vulnerable groups of the population and low-income residents who need social support and assistance are a particularly important aspect of this theme. Housing affordability is an object of study for social geography and is formed under the influence of the housing cost and the possible income of citizens to obtain it. The first and the second components have a territorial manifestation and they are implemented in different ways within the state in general and the regions in particular. The possibilities of applying an effective state policy at the national and regional levels are gaining considerable importance in order to resolve effectively this problem and the capabilities of a developed society in this matter. Today housing is a basic necessity. Housing performed only a protective function in the period of primitive society; now housing determines the living standards of the population and fulfils not only a protective function, but also the function of strength and energy renewal, the conditions of social reproduction. Thus, the study of the formation mechanisms of affordable and social housing based on the social and economic conditions of society requires a scientific approach and understanding of domestic and foreign practices.

Material and research methods. Significant experience and practices of housing market formation, housing provision, housing affordability and mechanisms of its functioning are fully disclosed in developed European countries, the USA, Canada and some Asian countries. Peter Boelhouwer in his book «Housing Systems in Western Europe: theory and practice» describes in detail the housing market experience in Western Europe (Peter Boelhouwer, 2010).

A thorough study of social housing in Europe has been conducted by researchers (Kathleen Scanlon, Christine Whitehead, Melissa Fernández Arrigoitia, 2014). The authors reveal the current policy and practice of social housing on the example of European countries. The scholars pay special attention to the analysis of the social housing system on the example of Austria, Denmark, Great Britain, France, Germany, Hungary, Ireland, the Netherlands and Sweden and the countries of Central and Eastern Europe. The researchers identify European trends in the social housing sector and opportunities for innovation and improvement in their study. The main topics of the authors are the role of social housing in the process of urban regeneration, privatization of social housing, financing models and the impact of the European Union state aid rules on the definition and financing of social housing.

In 2015, Kathleen Scanlon, Christine Whitehead, Melissa Fernández Arrigoitia in the article «Social housing in Europe. European Policy Analysis» thoroughly study the issues of the formation of social housing and European housing policy. The authors note in their work the importance of social housing in terms of investment in construction and regeneration, and in providing sufficient affordable housing for a wide range of European citizens. The researchers explain who lives in such housing and under what conditions, show the reasons for these trends and the consequences for the future provision of social housing. In particular, the authors evaluate how social housing contributes to the normal access of the residents to adequate standard housing at a price they can afford in different regions of the European Union (Kathleen Scanlon, Christine Whitehead, Melissa Fernández Arrigoitia, 2015).

The book «Estates on the Edge: The Social Consequences of Mass Housing in Northern Europe» (Anne Power, 1997) describes the decline and restoration of government-funded housing for low-income citizens in Northern Europe. The publication reveals the models of ownership, management and social housing permits, the interaction between landowners, investors, developers and other agents.

József Hegedüs, Martin Lux and Nóra Teller research the mechanisms of social housing in transition countries, they disclose the social housing policy in Central and Eastern Europe. The researchers describe the paths taken by the countries, considering changes in policies, working conditions of institutions and decisions taken to meet the housing needs of vulnerable groups of the population. They highlight the differences between the countries due to delay in reforms, assess the consequences of the peculiarities of the socialist economies and their effects on the formation of housing policy in Soviet times. The research examines changes in the housing policies of the countries that have recently become members of the European Union and the trends corresponding to such changes (József Hegedüs, Martin Lux, Nóra Teller, 2012).

Limitations, opportunities and financing mechanisms for social housing in the United States are described in detail in this article (James E. Wallace, 2010). The author gives examples of the forms of federal financial support for affordable housing and the role of developers and local public housing agencies in providing affordable housing.

Kathryn P. Nelson compared the amount of rented housing and the number of renters, taking into account their income. She claimed that during the 1980s, there were growing surpluses of apartments affordable to the renters with incomes between 50 to 80 percent of average income. By contrast, she concluded that housing shortages were high for the households with incomes below 30 percent of the average income (Kathryn P. Nelson, 2010).

Significant research into social and affordable housing is conducted by Russian scientists, where the issue of housing the population is a matter of the utmost urgency. Nikolaev S. in the article «Social housing at a new stage of improvement» argues that the problems of housing insecurity and material possibilities of the population cause increased demand for economy class housing not only in the sector of public financing of construction programs, but also in the private investment sector. The author considers possibilities of evolution of economy class housing within the term of physical wear and tear. (Nikolaev S., 2013).

Selyutina L., Evseeva E., Martinova A., Nektov V. and Nikolyuk E. consider the main directions of housing policy in the field of expanding social accessibility and improving the living conditions of low-income citizens. They think it is necessary to develop non-commercial forms of rental housing and attract investors in different ways to its construction. The authors argue the need to create conditions for bringing investors in this area (Selyutina L., Evseeva E., Martinova A., Nektov V., Nikolyuk E., 2015).

Shingalin A. (Shingalin A., 2014) in the article «New trends in the development of housing in a socially oriented market economy» proves that the implementation of mass modernization of the existing factory base of housing can provide the construction of the necessary social housing in the state. The transition of the existing and technical re-equipment of the housing base to the construction of social housing is an important condition for this.

Selyutina L., Bulgakova K., Bessonov M. and Paigusov A. confirm that the strategically important task of the state is not only to provide affordable housing for citizens, but also to create a comfortable and high-quality living environment. The authors of the research provide further ways to solve problems and prospects for the development of the social housing sector with the interaction of local authorities, business and communities. The authors pay special attention to the social and economic significance of this specific area, which includes production and services for the population. Solutions of the state program of providing housing for the population have been analyzed by the authors. It is necessary to create attractive conditions for housing developers, ensure affordable lending for the construction industry, so that housing construction remains the driving force of the construction industry and the economy as a whole (Selyutina L., Bulgakova K., Bessonov M., Paigusov A., 2016).

However, the housing market of our country and the housing policy of Ukraine differ significantly from the housing market and the policy of European countries. The main reasons of this situation are the excessive share of real estate in private ownership, outdated housing stock and the absolute unregulated rental market. In addition, there are no directed housing policy and housing market mechanisms. At the same time, the problem of providing housing for the population is quite acute, social and affordable housing formation has remained a problem in Ukraine in recent decades. This determines the relevance and timeliness of the subject of this study.

The aim of the research is to study the state and formation mechanisms of social and affordable housing in Ukraine, evaluate them and give recommendations for improvement. The research methodology of social and affordable housing involves the analysis of world practices of providing housing for the population, assessment of the domestic regulatory framework on this topic and analysis of housing supply and demand.

Evaluation of housing affordability for the population can have many variations, depending on the availability of statistical information and the specifics of the housing market. Each of them has both advantages and disadvantages. Traditionally, the initial or basic index of housing affordability is the index that is calculated according to the UN method – HABITAT (Official site of the UN HABITAT) in foreign and national scientific literature. This index is determined by the number of years required for the average family, on condition that income is directed to housing (1).

$$AI = C/I, \quad (1),$$

where AI – is the affordability index; I – is the average household income earned by one person, UAH per year; C – is the average housing cost, UAH.

The National Association of REALTORS of the USA determines the affordability index according to the formula that takes into account the income required to obtain and service a long-term mortgage

$$AI\ (I1 \cdot 100\%) / I, \quad (2)$$

where I1 – is the average family income, monetary units; I – is the income which is necessary for obtaining and service of a long-term mortgage loan required to purchase a medium-value housing, monetary units.

The adapted HABITAT method is used in the Russian Federation, it assumes that the household consists of 3 persons, and the area of the apartment is 54 sq.m.

$$AI = (Cm \times 54) / (I \times 3 \times 12), \quad (3)$$

where Cm – is the cost of 1 sq. m .; I – is the average household income, rubles; 54 – is the area of a conditional apartment, sq. m .; 3 – is the number of household members, persons; 12 – is the number of months per year (Selyutina L., Bulgakova K., Bessonov M., Paigusov A., 2016).

This method is more adapted, but it does not take into account the consumer spending of households at least at the subsistence level. The housing affordability ratio, which includes current household expenditures, is called modified.

There are a number of other methods of determining housing affordability through the calculation of available savings, the opportunity to invest the part of income in assets, if there is available housing that can be sold. According to the standard UN methods, the assessment of housing affordability is carried out using the affordability coefficient AI and is used for inter-state comparisons of the population living standards. It is calculated as the ratio of the average (median) price of a typical apartment to the total annual income of the average (median) household and shows the number of years during which a family can accumulate from current income the amount needed to buy an apartment. A typical apartment is an apartment the total area of which is equal to the value of the average housing of the population for a given country (it is 30 sq. m. per person in Eastern European countries, 40 sq. m. per person in Western European countries, 70 sq. m. per person in the US), multiplied by the average household size. Thus, according to the standard method, the affordability coefficient of the residents AI is calculated on four variables, expressed by the average (median) values for the given country: the prices of 1 sq. m of housing, size (total area) of an apartment according to the current level of providing housing for the population, annual per capita income, size (number of members) of the household.

We try to adapt the above method in our research, taking into account the following characteristics. As a basis we take a young family in which there are two working persons with average income for the region minus expenses at the subsistence level. In this case, the young family has mostly one or two children and they are planning to purchase a small one or two-room apartment (or a two-bedroom apartment with a modern construction approach) with the area of 43 sq. m. Developers carefully study housing demand, and they consider that such an area corresponds to the area of most requested housing today. In particular, analysts say that 62% of one-bedroom apartments in new buildings have an area from 35 to 50 sq. m., i.e. the average size of such apartments is 43 sq. m. The average 1-bedroom apartment is about 40 sq. m, in the economy-class and comfort-class apartments, and 47 sq. m. in the business-class. As it can be seen from the above data, the most popular may be a comfort-class apartment in a residential complex with the area of 43 sq. m. Considering the above facts the housing affordability formula is

$$AI = (Cm \times 43) / (I \times 2 - (2 \times 12 \times SL)), \quad (4)$$

where Cm – is the cost of 1 sq. m .; I – is the disposable income per person, UAH; 43 – is the area of an apartment unit, sq. m.; 2 – is the number of working household members, persons; 12 – is the number of months a year, SL – is the subsistence level of the citizens income.

The main methods of this study are literary, analytical and statistical, comparative, balance sheet and regulatory. The QGIS geographic information system has been used to visualize the data.

Results and their analysis.

The concepts of «social» and «affordable» housing are not fully regulated and these concepts are often used as synonyms in Ukraine. At the same time, «social» housing is regulated by the Law of Ukraine «On Social Housing» from 2006. «Social» is housing of all forms of ownership from the social housing stock (except social dormitories), which is provided free of charge on the basis of a fixed-term lease agreement to the citizens who need social protection. Social housing is not subject to rent, reservation, privatization, sale, gift, buy-out and mortgage. The social housing fund is formed by the local authorities through the construction of new housing, reconstruction of existing and re-equipment of non-residential buildings, donated housing or housing confiscated on the basis of court decisions or declared ownerless, making over a share of living space in new buildings by the developers to local authorities, the use of private housing stock on the contractual arrangements, etc.

The relevant «Realization procedure of the rights of vulnerable citizens to receive housing» provides an opportunity to receive social housing for the citizens whose average monthly income (per family member) does not exceed the statutory subsistence level. Accordingly, the Kyiv City Council adopted a decision «On the establishment of a social housing fund» in early March 2010. However, such a decision provided district administrations with the power to organise a queue, and stipulated the impossibility of social housing privatization, i.e. a significant corruption component was initially established. Moreover, the experience of most European countries shows that residents can buy social housing later under the conditions of living in it for a certain period of time.

The idea of social housing is generally understandable. First of all, it helps to resolve the housing issue for the citizens who, due to health problems, lack of work or limited income, are unable to purchase housing at market prices. In general, the principles of providing social housing are similar in different countries around the world. However, there are some differences both in price criteria and in the level of citizens' income. Single mothers, large families, retirees with a small pension are the priority categories that primarily receive state assistance in resolving housing issues in all European countries.

In addition, there is a distinction between notions «free» housing and «social» housing. Mostly these concepts are not identical in European countries. The main criterion for providing social housing is income per family member. It is believed that a family or a single adult should not spend more than 25-35% of the total income on rent or mortgage payments. This concept is called «social» or «commercial» housing affordability. If the item «payment for housing» exceeds 30-35% in the income structure of an ordinary family, this is a sufficient argument for obtaining «social» housing. The state must help these citizens to bear the housing cost in the form of housing subsidies or by providing housing with a fixed low rent.

«Social» housing programs have been actively created at the state level since the 1950s and 60s in Europe. Today, social housing has a significant share of the housing stock of developed European countries. For example, in France 20% of apartments in new buildings are given to low-income citizens under the law. In Germany, 25% of the housing stock is used for social needs, 23% in Austria, 21% in the UK, 36% in the Netherlands, 27% in Denmark, 30% in Spain, 27% in Sweden.

As a rule, social housing is managed by the municipalities, cooperatives or housing associations. At the same time, modern social housing in European countries does not consist only of small apartments. Today,social housing can be apartments, as well as houses, which in their consumer characteristics are not inferior to apartments that are offered at market prices. The main thing is that the municipality can rent housing below the market price, but not provide the equivalent of free state lifelong ownership.

The main condition for the organization of providing social housing for the population is to build a lot of housing cheaply. Then there is the question of construction financing. The experience of Great Britain is very interesting in this direction. Social housing is rented out, and the profit from the rent payments is immediately used to build new homes. In Germany, money from the privatization of social housing is immediately used for its new construction. In general, the experience of European countries shows that creating favourable conditions for public and private partnership is the key to social housing construction to a significant extent. And the permission to privatize social housing for certain terms of its use and other conditions allows to social housing to become affordable, successfully solving housing problems of the citizens and creating comfortable living conditions for the residents.

The concept of social housing appeared in Belarus in 2013. It is provided on the conditions of an indefinite loan. Disabled people, orphans, large families, people who are homeless as a result of emergencies or natural disasters can apply for it. Social housing can neither be privatized, nor rented out, nor sold, it is owned by the state.

In fact social housing is not built in Ukraine. The norm of receiving 15–20% of apartments for free transfer from developers to the citizens was fulfilled earlier. However, such distribution was often corrupted and did not allow for the effective formation of a social housing stock. Since 2011, according to the Law of Ukraine «On Regulation of Urban Development» «it is prohibited to require from the construction client to provide any services, tangible or intangible assets, including the construction of facilities». In addition, the obligatory payment of a share contribution to the development of the locality infrastructure by the construction client will be abolished from 2021. There is no general information in Ukraine on social housing volume and demand for it in the country or in the regions. The appropriate policy of providing social housing for the population is unclear and fragmentary.

The formation of affordable housing in Ukraine has a long history. Thus, in 2007 the Presidential Decree «On measures to build affordable housing in Ukraine and improve housing» was adopted. The Law of Ukraine «On Prevention of the Influence of the Global Financial Crisis on the Development of Construction and Housing», «Procedure of Providing State Support to Provide Citizens with Affordable Housing» and the Law of Ukraine «On Amendments to Certain Legislative Acts of Ukraine on Housing» were adopted later. According to the corresponding documents, «affordable housing» includes residential apartments and houses and they are built with state support. In general, these legislative acts provide allocation of 0.5% of the GDP annually for the construction of affordable housing , provision of one-time state aid to citizens, rental housing for a period up to 30 years with the subsequent possibility of its buy-out, free land plots for the construction of such housing. State aid determines the payment of 30 percent of the construction (purchase) cost of affordable housing and/or the provision of preferential housing loans by authorized banks.

Demand for housing in our country is considerable. According to analysts of the Confederation of Builders of Ukraine (CBU), 6 million Ukrainians need their own housing now, i.e. almost one in seven Ukrainians need housing. Also, «70% of the housing stock in Ukraine is old and dilapidated. At the same time, 7.5% of the housing stock, which is 75 million m² according to official data, is completely uninhabitable. Only 11% of the population lives in relatively new housing (built after the 1990s)». According to the data of the State Statistics Service «Socio-demographic characteristics of households in Ukraine in 2018», 53.7% of Ukrainians live in overcrowded apartments and houses, and the share of satisfied residents (53.8%) and very satisfied (1.8%) with their living conditions is 55.6%. 95.3% of housing is privately owned, and state and employment related housing make up 0.5 and 0.3% of all housing. There is no official figure for the population's housing needs today. This statistic has not been updated after 2015 when the figure was 650 thousand families and singles. However, it is difficult for most residents of our country to improve their living conditions because of the low income and the lack of effective housing policy, including affordable housing loans. To assess housing affordability, we can use the UN HABITAT method, adapted to the realities of our state.

It is calculated according to the official data of the group of companies UVECON (the cost of residential real estate) and the data of the State Statistics Service of Ukraine.

* The index of housing affordability (years) is calculated according to the housing cost in the regional center. The calculation was made as the average value of the housing cost in Kyiv region, Boryspil, Brovary, Bila Tserkva.

Therefore, according to the obtained results (Fig. 1), we can observe a general trend towards increasing housing affordability in Ukraine. At the same time, real affordability indicators are still quite low and characterize a fairly long period of savings by the population to buy housing. It should be noted that in 2007 there was a so-called «price bubble» in the country, which was characterized by excessive housing prices. At the same time, the income of the population was too low to be able to solve their housing problems in a short period of time. Housing affordability for the population was growing significantly in the end of 2019. The average affordability value is 9.2 years, which is almost six times higher than in 2007. The affordability index in the state varies considerably. The highest indicators are in Kyiv, Zaporizhzhia, Dnipropetrovsk, Kyiv and Sumy regions. The lowest values are typical for the western region of the country, in Zakarpattia, Chernivtsi, Ternopil, Lviv, Rivne and Volyn regions. They are in the range of 11.5 – 16 years, which distinguishes them four times from the best indicators. Housing is considered affordable within a period of three years according to the world practice.

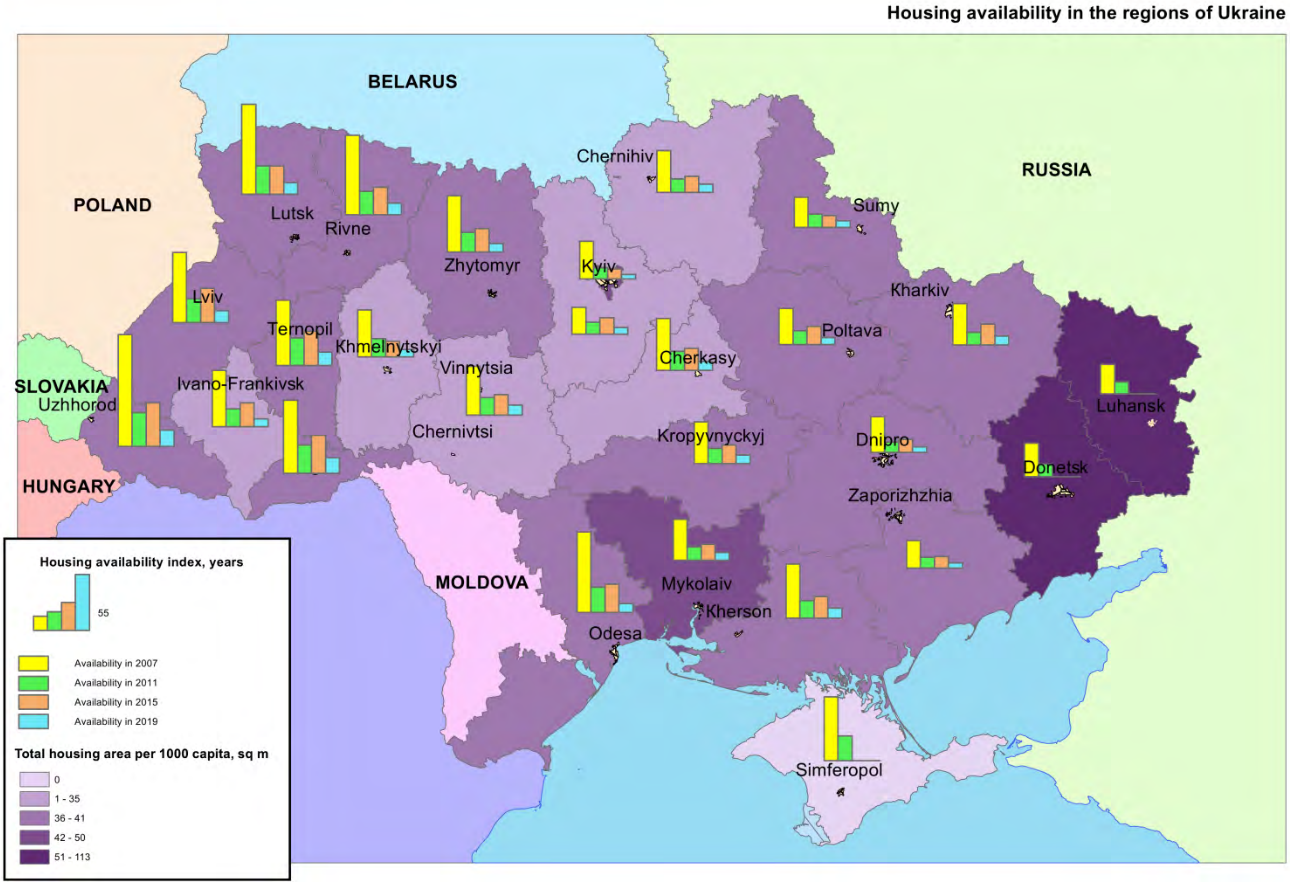

Fig. 1. Housing affordability in the regions of Ukraine, years

Such affordability is directly related to the volume of housing construction and commissioning. Speculatively high prices in the early 2000s led to positive growth trends in housing construction and commissioning.

Therefore, we can see a sufficiently dynamic growth rate of construction volume considering the crisis in the state's economy in 2008-2009 and in 2013-2015. At the same time, high rates of housing construction and its commissioning were observed during the crisis of 2013-2015.

The relative indicator of the construction volume and housing commissioning is significant, which shows the level of housing demand and the

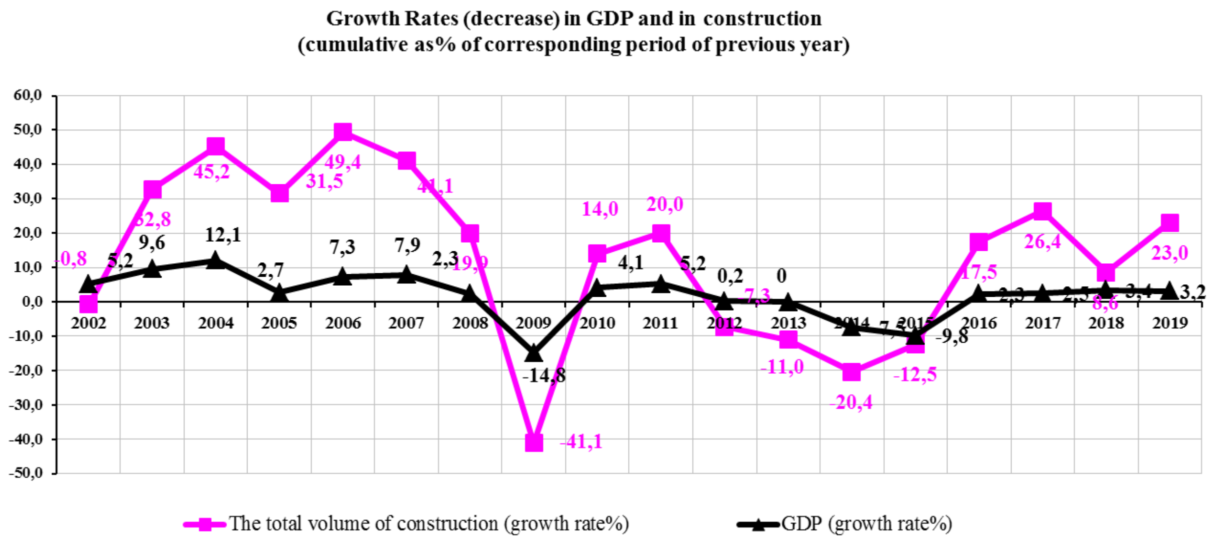

Fig. 2. Dynamics of GDP growth (decrease) and volume of construction work
Compiled according to the State Statistics Service of Ukraine.

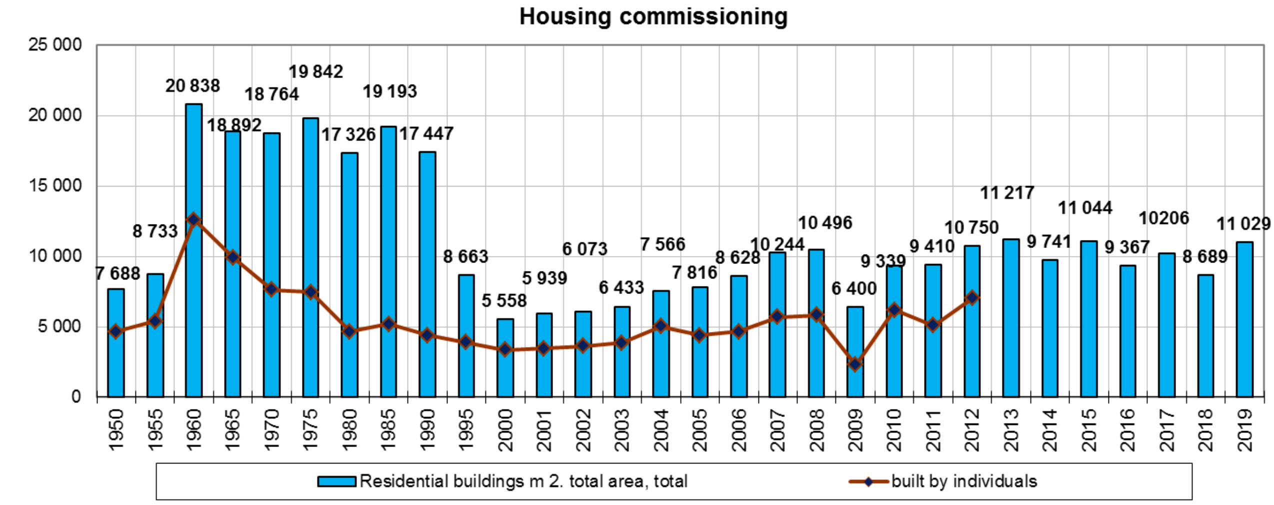

Fig. 3. Housing commissioning. Compiled according to the State Statistics Service of Ukraine.

attractiveness of the territory for living. P.O. Masliak in his article «Quantitative assessment of the socio-geographical location of the territory» argues (Masliak, 2019) that the assessment of per capita housing construction in the regions of Ukraine has made it possible to identify << radical changes in the assessment of the socio-geographical situation of different regions of Ukraine for the last five years». According to the author, such changes are in the reorientation of all social processes in the western region of the state. The scientist considers that «the western part of our country is consciously and subconsciously considered as a safe territory, which not only now but also in the future will not be affected by war». In addition to security, the income inhabitants of the western region, including the currency they earn abroad, also remain an important factor. Thus with average Ukrainian values of the indicator for putting accommodation into use per1,000 people in 263.5 sq. m , the leaders are Kyiv (1052.2), Ivano-Frankivsk (550.4), Chernivtsi (544.7), Lviv (517.2), Odessa (459.2), Volyn (424.3), Zakarpattia (404.7) regions and the city of Kyiv (381.2) . Luhansk (9.8), Donetsk (15.3), Zaporizhzhia (53.2), Kirovohrad (76.5) and Mykolaiv (99.6) regions are among the outsiders. The construction growth in general has a positive effect on housing affordability.

Mortgages were at the rates of 18-20% per annum in our state in the end of 2019, which was high enough for their mass introduction for the purchase of accommodation. Lower mortgage rates (14-15%) are possible only if the borrowers meet a number of requirements and are available only to certain categories of the citizens due to certain requirements of banks for mortgages. Real mortgage rates in 2020 ranged from 18% (as financing by state banks for partial construction projects) to 25% (micro-mortgages, when the borrower needs a small amount for a purchase at a rate of 10-15% of the property value). However, the housing market expects rates of about 10% per annum, but the experts consider that the main reasons for the complexity of their implementation are the moratorium on recovery of property on foreign currency loans, insecurity of creditors' rights and non-transparency of the primary housing market. The share of mortgage transactions was only about 3% of total transactions in the market last year.

Supporting citizens through government programs is an important condition for ensuring housing «affordability». There are currently more than 20 programs to support citizens in purchasing housing in Ukraine now. However, they do not meet the overall housing demand at a sufficient level, and their financing is often on a residual principle. The first program is soft loans for young people. 64.3 million UAH has been allocated for this program to compensate only existing loans in 2020. The program has financed only existing loans from the state budget since 2015. At present, the financing of subsidized loans to young people is implemented only by local budgets at the level of local housing programs. The crediting program for IDP and ATO (JFO) has been suspended and does not work due to lack of funds. The Cheaper Mortgage Program has not been funded since 2015. The program of partial compensation of the interest rate of commercial bank loans to young families and single young citizens for construction (reconstruction) and purchase of housing has been financed since 2009 only under previously concluded agreements. Financing of new loan agreements is not provided by the State Budget on the ACAB Credit Program in 2020. This indicates that nonpriority state support of the housing sector lacks regulation .

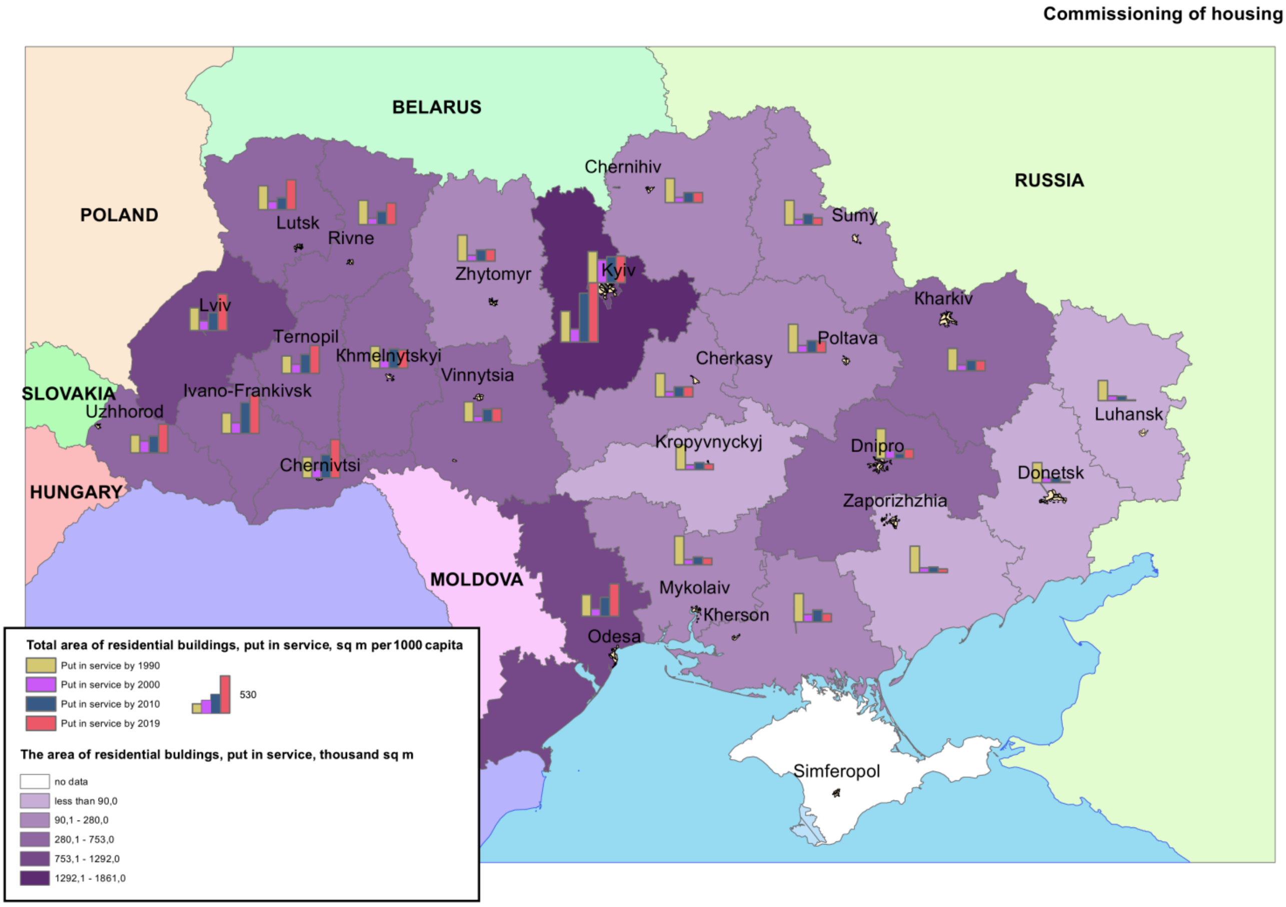

Fig. 4. Housing commissioning. Compiled according to the State Statistics Service of Ukraine.

Conclusions.

Therefore, the housing market needs clear legislative regulation and the creation of effective housing policy in the state. The lack of such a policy gives rise to a number of different housing programs, which are not funded and cannot be effective in solving the housing problem of the majority of our citizens. As a result, the unregulated rental market is flourishing due to the impossibility people find in obtaining money to purchase their own homes. The provision of social housing for the population today is poorly implemented and has no statistical support. Although housing affordability has been improved in recent years due to increase in the population's income and supply growth of new housing, it cannot dramatically be improved without effective mortgages. Despite the inefficiency and fragmentation of housing support programs, affordable mortgages would be a good alternative in solving the housing problem. The combination of affordable mortgages with an increase in the real estate tax would encourage owners of «additional» housing to rent it out and increase the supply on the market.

The main task of an effective housing policy should be creation of the most favourable conditions for housing. These are opportunities for the affluent segments of the population to buy housing on their own or lease it by means of creating clear and favourable conditions for mortgage opportunities, creation of effective housing programs at the national and local levels. This increases housing affordability especially for the middle class. The formation of social housing through state support is for the vulnerable part of the population. It should be based on a radical change of approaches to the mechanisms of its formation. The state should become an investor and customer of the social housing construction, and reduce its cost by redirecting funds from housing subsidies to the construction of new social housing. There must also be a clear distinction between social and market housing affordability. Social affordability should take into account the time during which the relevant sectors of the population should realise their right to housing with differentiated living expenses within the «acceptable» share of a family budget. Housing standards and conditions of living space rationing, utilities rationing and other housing maintenance costs should be reviewed. It is necessary to introduce the creation of housing cooperatives or associations for the construction and management of social housing in the lands allocated for this purpose by local authorities and use the experience of foreign countries. Such organizations should have a number of tax benefits and preferences.

In addition, the qualitative aspect of providing housing for the population is very important, taking into account the housing comfort, its design, the convenience of housing and courtyards, installation of sports facilities and social infrastructure.

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The use of SMART technologies in censuses: world experience and prospects for Ukraine

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Abstract. Current records of the population in Ukraine are carried out systematically by the relevant bodies and departments of statistics of various levels. It provides an opportunity to quickly obtain the main statistical characteristics of the population in a short time. However, other important parameters of the country's population, such as ethnic structure, literacy, education, property status and other important indicators, do not take this into account. They can only be installed by census. The article analyzes the results of censuses of some countries of the world, which decided to introduce innovative technologies - SMART-phones, Internet resources - into this process. The study revealed the advantages and disadvantages of such a census format. In the course of the scientific research, statistical indicators of censuses using innovative technologies, which were conducted in the respective years in the USA, Canada, Lithuania, Estonia, Brazil, Australia were analyzed. The basic normative provisions concerning the census procedure in Ukraine, covered in the main legislative documents, as well as the materials of the Institute of Demography and Social Research named after M. V. Ptukha of the National Academy of Sciences of Ukraine, which develops the program and questionnaire of censuses in our country. SWOT analysis of the use of SMART technologies in the census was conducted to identify the advantages and disadvantages, as well as to outline the prospects and threats of the census using innovative technologies. Benefits include the ability to quickly collect and organize information, low census costs, compared to the traditional option. The main disadvantages of the latest census should be mantioned the need to develop expensive software with a high degree of personal data protection, as well as the complexity of fully transitioning the census to the online platform. Studying the experience of countries that have already conducted population censuses using innovative technologies indicates the importance of legally binding participation in the census questionnaire (either electronically or traditionally). The possibility of conducting two stages of population census in Ukraine in 2020 is indicated: in the online mode and in the traditional format. Such an approach to the census procedure will allow the coverage of respondents in all regions and settlements of Ukraine.

Keywords: census, innovative technologies, statistics, population geography, demogeography

Застосування SMART-технологій під час переписів населення: світовий досвід і перспективи для України

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Анотація. Поточний облік населення в Україні здійснюється систематично відповідними органами та управліннями статистики різного рівня. Він дає можливість оперативно отримати головні статистичні характеристики населення країни у стислий термін. Однак інші важливі параметри населення країни, зокрема, етнічну структуру, рівень грамотності, рівень освіти, майновий стан та інші важливі показники такий облік не враховує. Їх можна встановити лише шляхом перепису населення. В статті проаналізовано результати переписів населення окремих країн світу, які наважились на впровадження в цей процес інноваційних технологій – SMART-телефонів, інтернет-ресурсів. Дослідження дало можливість виявити переваги і недоліки такого формату перепису населення. Під час наукового дослідження було проаналізовано статистичні показники переписів населення з використанням інноваційних технологій, які були проведені у відповідних роках у США, Канаді, Литві, Естонії, Бразилії, Австралії. Вивчено основні нормативні положення, які стосуються процедури переписів населення в Україні, що висвітлені в основних законодавчих документах, а також опрацьовано матеріали Інституту демографії та соціальних досліджень ім. М. В. Птухи Національної Академії Наук України, який розробляє програму та анкету переписів населення в нашій країні. Для виявлення переваг та недоліків, а також окреслення перспектив та загроз перепису населення з використанням інноваційних технологій, було здійснено SWOT-аналіз застосування SMART-технологій під час перепису населення. Серед переваг: можливість швидко зібрати і систематизувати інформацію, низькі затрати на проведення перепису, порівняно із традиційним варіантом. Основними недоліками новітнього перепису варто вказати необхідність розробки дорогого програмного забезпечення із високим ступенем захисту персональних даних, а також складність повного переходу перепису населення на он-лайн-платформу. Вивчення досвіду країн, які вже проводили переписи населення із застосуванням інноваційних технологій, вказує на важливість закріплення на законодавчому рівні обов'язкової участі у процедурі опитування під час перепису (у електронному або традиційному вигляді). Вказано на можливості проведення двох етапів перепису населення в Україні у 2020 році: у он-лайн режимі та традиційному форматі. Такий підхід до процедури перепису дозволить охопити респондентів в усіх регіонах і населених пунктах України.

Ключові слова: перепис населення, інноваційні технології, статистика, географія населення, демогеографія

Introduction.

One form of population accounting and survey is census, which, according to recommendations of the United Nations since 1961, is conducted every 10 years in each country of the world. The censuses make it possible to visualize the basic parameters of the population (number, sex and age structure, national composition, level of education, literacy, property status, income level, etc.) and to identify trends of further development of a society of a country, to distinguish the main problems and disparities.

The first population censuses in the world began to take place as early as 4.5-5 thousand years BC in the territory of Ancient India, China, Sumer. And the first modern-day census was conducted relatively recently − in 1846 in Belgium. Its program has become the basis for all modern population censuses in the world.

Modern technologies, such as Internet resources, make it possible to streamline and accelerate the process of collecting and processing statistics during censuses. In addition, as shown by the practice of countries that have already tested SMART technologies in conducting the census, this process can significantly save the money allocated for the census procedure, to conduct it quickly and efficiently. In 2020, it was planned to be held in Ukraine, during which partial use of SMART technologies is planned. Therefore, it is important to analyze all the advantages and disadvantages of the newest technologies that will be applied, comparing with the foreign experience.

Materials and methods of research.

The research used statistical indexes of censuses which used innovative technologies that were conducted in the United States, Canada, Lithuania, Estonia, Brazil, Australia in the relevant years. The SWOT analysis was used to analyze the advantages and disadvantages, as well as the prospects and threats of conducting a census using SMART technologies. The basic normative provisions concerning the census procedure in Ukraine, covered in the main legislative documents, were studied: the Law of Ukraine "On All-Ukrainian Population Census" (Adoption on October 19, 2000, No. 2058-III, Verkhovna Rada of Ukraine), 2000, No. 51-52, Art. 446) 4.; the Regulation "On the State Statistics Service of Ukraine", approved by the Decree of the Cabinet of Ministers of Ukraine on 23.09.2014, No. 481, as amended, approved by the Decree of the Cabinet of Ministers of Ukraine Decree on 10.12.2019, No. 1072; the Standard Law "On Official Statistics" (developed within the framework of the project of ninth tranche "Accounts of the development of the United Nations (UNDS) for Eastern Europe, Caucasus and Central Asia" (approved by the Conference of European Statisticians, 27−29 April, 2016) .

Along with the collection, processing and publication of census results, as well as the current census, there is a need to preserve a large array of statistical information in digital form, to counteract the "leakage" of personal data of citizens. And this creates a number of new challenges for scientists in countries that plan to record the population using innovative technologies. These pressing issues are reflected in the research of modern scientists who consider the use of new technologies for creation of large databases that include huge amounts of statistical information (Chatfield, Ojo, Puron-Cid, Reddick, 2018), explore the application of SMART-technologies for statistical surveys of the cities (Bação, Henriques, Antunes, 2018) and for the current population accounting for the conditions where the census is impossible (Wardrop, Jochem, Bird, Chamberlain, Clarke, Kerr, Bengtsson, Juran, Seaman, Tatem, 2018).

To study the indicators of the First All-Ukrainian Population Census of 2001, as well as to identify the main shortcomings of its conducting, the data from the official website of the State Statistics Service of Ukraine (Official page of the First All-Ukrainian Population Census of 2001 - https://www.ukrcensus.gov.ua/eng/) notice / news.php) has been studied.

To get acquainted with the historical aspects of censuses on the territory of Ukraine and in the world, as well as current trends and possibilities of demographic population survey, the scientific achievements of foreign and Ukrainian scientists − geographers, demographers and economists were studied, such as: O. Grishnova, I. Kalachova, I. Kurilo, E. Libanova, L. Lisogor, V. Steshenko, L. Tkachenko and others; the materials of the Institute of Demography and Social Research named after M. V. Ptukha of the National Academy of Sciences of Ukraine were processed.

Results and their analysis.

Censuses in the countries of the world have always been carried out by means of questionnaire survey. The development of modern information technologies makes it possible to digitize such questionnaires and to conduct surveys online or using e-mail. For the first time, innovative technologies for population census applications have been applied in the United States and have shown good performance.

With the development of the Internet and its accessibility in most regions of the world, every resident can now, without any problem, at any onvenient time to send his data directly to the service or statistics department in their country.

One of the typical features of the introduction of SMART-technologies in the process of population census is the leveling of differences in socio-economic development of different countries of the world. This is confirmed by the fact that the first population censuses via the Internet were conducted in economically highly developed countries − the USA, Canada and Australia. Subsequently, these forms of population accounting began to spread rapidly in other countries, and became especially popular in the group of countries with medium economic development − Brazil, Lithuania, Bulgaria and others.

Canada was the innovator in censuses and the first country to use SMART technologies. The first census using the electronic form was conducted here in 2006. Failure to participate in the census imposed a fine or threatened imprisonment. And already in 2011, participation in the census was voluntary for every inhabitant of the country and provided:

- passing a traditional survey using a paper census questionnaire (filling out a paper form). In this

Table 1. Use of SMART technologies duting census in some countries of the world

Country	Year of the census	Population at the time of the census, million people	Share of population surveyed using SMART technologies,%	Census cost per capita, in USD	Census tools and means of identifying the persons who participated in the census
USA	2010	308. 75	-	47	Submission of data into electronic census forms by instructors
Brazil	2010	190. 75	100	4.8	LG 750GM Smart Phones, Special Software
Canada	2011	33. 48	54	17.4	Website www.census2011.gc.ca, e-questionnaire, personal access number provided by e-mail, call to the call center by the “green number”
Australia	2011	22.34	10.2	19.0	Website www.abs.gov.au, e-questionnaire, e-number
Bulgaria	2011	7.37	41	4.3	Email, Information System Module “Census”
Lithuania	2011	3.05	34	3.8	Website www.esurasymas.lt, e-questionnaire, personal citizen number, internet banking or ID-card
Estonia	2012	1.34	63	19.0	Website www.rel2011.ee, e-questionnaire, ID-card, Mobil-ID, internet banking passwords Swedbank, SEB (U Net), Sampo

case, each resident of the countries received from the statistics department an envelope with forms, which had to be filled and sent within the specified time. Each package had an extra envelope that filled in the forms and was sent to the Statistical Office address (the envelope already contained a sticker indicating the return address). Each resident was given his or her unique ID of the survey participant;
- filling in an electronic form on the relevant website of the statistics service.

Conducting the survey appropriately made it possible to optimize the costs of conducting the census procedure − only 15.2. USD per capita.

In 2010, the United States first used SMART technologies when conducting a census. In addition, more than 65.000 instructors have been recruited to perform the census in the traditional way. By the way, in the US, the census procedure is mandatory for every resident, and evasion of it implies a fine of 100 USD. False information filing − 500 USD.

The census in the United States involved several stages − the formation of a single population base for the country, for which a properly trained instructor had to go around every home, every home and record all the people who live there. In the future, this information was used for rescue, social security, Google map optimization and more.

Despite the clear and deliberate organization of the census and the use of the latest technologies to conduct it, only 70% of the country's population participated in the 2010 U.S. Census. The introduction of information technology to collect data during censuses has revealed not only the positives, but also a number of disadvantages, including the unreliability of the system and the storage of individual data. Therefore, in addition to the online census, the United States retains the traditional census form.

Of the European countries, Lithuania (2011) was the first to decide to use SMART technologies for the census procedure. At that time, 34% of the country's population (1.039 million people) were polled. The small number of respondents who took part in the electronic survey was caused by a number of important problems with the Lithuanian population census (Marcu, 2011) :
- low proportion of people using Internet resources (less than 60%);
- the electronic questionnaire was created only in Lithuanian;
- the obligation to pass the population census has not been approved at the legislative level.

Thus, the majority of the Lithuanian population still underwent the census procedure according to the classical scheme − answering the questions of the volunteer-interviewers.

Among the main advantages of online census in Lithuania:
- significant cost savings (out of the 10 million lats allocated for the census procedure, only 6 million was spent due to the reduction of the amount of human resources involved in the work);
- the ability of one person to fill in the questionnaires of all his or her family members living with him / her;
- reducing the number of classic Eurostat questionnaires by more than twice.

An online population census conducted in 2011 in Bulgaria has shown significant benefits. The advanced form and timeliness of the procedure enabled it to become one of the most successful first censuses in the world using innovative technologies. It allowed to cover 42% of the country's population. An e-mail was sent to each resident for the census, allowing them to access their office at the census site. In addition, 46.000 instructors were recruited to perform the census in the usual manner.

Modern information and communication technologies have been successfully used in Estonia in the 2012 census. The disadvantages of the censuses of Lithuania and Bulgaria were taken into account, which made it possible to interview more than 63% of the population of the country and to collect accurate statistical information.

The main advantages of online census in Estonia:
- respondents were interviewed using questionnaires developed in English, Russian and Estonian;
- the necessity of passing the census was fixed at the legislative level and a fine of 2 thousand EUR was provided for a failure to comply with this resolution;
- a powerful arsenal of digital tools (ID-cards, Internet banking, Mobil-ID, etc.) was used to identify the persons who were undergoing the census and to keep their private information;
- in addition to the Internet census, there was a traditional survey of people using laptops.
- this census organization reduced the cost of the procedure to 19 USD per capita.

Brazil is the first country to conduct an electronic census of the population, completely abandoning traditional paper. Brazil's experience with the use of the latest census tools and methods is most successful. In the short term it was possible to:
- accurately determine the residence of each

Brazilian family (through the use of GPS technologies);
- conduct population surveys in all regions of Brazil. This is a great achievement, especially given the fact that individual sections are difficult to access due to the complexity of the terrain;
- get accurate information on all the questions provided in the survey form;
- reduce the time for statistics to be processed from several years to several months;
- minimize the cost of the census procedure − 4.7 USD was spent for each census resident.

To organize and conduct the census in Brazil, 150.000 smartphones were purchased and a special census program was installed on them. All data from each smartphone was transmitted to one of the 7.000 static data centers hosted nationwide by GPS navigation.

Analyzing the peculiarities of the use of SMART-technologies in conducting modern censuses, we can note that in different countries the latest survey tools and methods were used:
- survey via the Internet;
- email survey;
- smartphone survey.

SWOT analysis is one of the most effective tools of socio-geographical research that allows to study the phenomenon from different perspectives − to outline the advantages, highlight the disadvantages, formulate prospects and threats in its development.

Table 2. SWOT-analysis of the use of SMART-technologies during the census

Advantages	**Disadvantages**
- the ability to gather quickly relevant statistical information and transfer it to statistical centers; - reduction of time for processing statistical information; - safety of the interviewing procedure (instructors will not have to directly contact people who belong to the marginal sections of society); - total coverage of all residents in the survey during the census, regardless of the territory of residence, employment and other reasons that hinder the census procedure; - an opportunity to receive complete information that will reflect the real indicators of the population in general, the share of pensioners, the real level of income of the population in particular, which will allow for the effective implementation of national and regional social policy; - 2 times less staff will be involved in conducting the census procedure; - the respondent can take the survey at his or her convenient time by registering on the census site; - one household representative can fill in the details of all his / her members; - anonymity of the survey during the census; - significant savings of the state budget funds.	- requires the development of special software; - a lengthy procedure of preparing for this type of census, - the need to check constantly the system software; - training of specialists who will receive and process statistical information is required; - lack of accessibility of the Internet for all residents of the country; - there is a problem of ensuring the confidentiality of the data of the census participants (they can be easily intercepted on the way from the participant's computer to the statistical service server); - the need to develop complex cryptographic programs; - inability to identify the data subject; - the need to conduct a traditional census with the involvement of volunteer instructors alongside the Internet census, since many people (elderly, children or disabled) will not always be able to cope with the latest technologies or simply do not have access to the Internet because of their low income; - the inability to conduct an online census in mountainous areas where there is no connection.
Threats	**Prospects**
- there is a risk of providing inaccurate information that is difficult to verify, especially when one household member fills in a form for each person who is a household member; - "leakage" of personal data due to defects and malfunctions of the system or network is possible; - the problem of inclusion in the census of children studying abroad.	- a significant reduction in the cost of the census compared to the traditional option; - census of the Ukrainian population with the use of SMART-technologies requires certain innovations at the legislative level.

By conducting a SWOT analysis of the use of SMART technologies during the census in Ukraine, we can conclude that such a census will have far more advantages than disadvantages. Its main positive points will be, then, as follows:

- saving of public funds allocated for the census procedure (and this is especially relevant for Ukraine, whose economy is in crisis);
- anonymity of the survey − for the first time in the census history of our country a special procedure of encryption of the data of the respondents will be applied with their corresponding registration number;
- the ability to conduct a population census procedure quickly and to survey all regions of Ukraine, as well as to process statistical data in a short time, etc.

The main disadvantages of the latest census should be the need to develop expensive software with a high degree of personal data protection, as well as the complexity of fully transitioning the census to the online platform. However, despite the high level of technological ability of Ukrainian society, access to the Internet is not available throughout Ukraine. Particular difficulties with the Internet census can occur in rural areas of Chernihiv, Zhytomyr, Sumy regions, where there are large number of villages with a population of up to 50 people, mostly elderly people. The young people left these territories to study and work in the cities, so there is no need to talk about the latest technologies.

The task for the Cabinet of Ministers in the near future should be to develop a legislative framework for responsible population participation in the census.

Discussion.

Conducting the First All-Ukrainian Population Census has revealed the positive sides, as well as some shortcomings that should be taken into account in the following procedures of similar population registration in Ukraine. At that time, about 108 million UAH was spent on population registration, and a large number of instructors of different levels were involved and were trained. But even with such huge efforts, there were still some inconsistencies and inaccuracies during the procedure (not all the questions from the questionnaire were fully understood by the respondents, and some of them simply refused to answer, etc.) (Zastavetska, Zastavetsky, 2019).

The population census, which was scheduled for 2020, is supposed to take place for the first time in our country's history with the use of SMART technologies - smartphones, tablets, Internet surveys on websites, etc. The experience of foreign countries, which have already conducted similar censuses, shows that it is still not necessary to give up traditional census paper forms. Therefore, a large number of trainers will be involved in the population registration procedure, who will record statistics in paper forms or on electronic media (tablets, smartphones).

In order to study all errors during the census procedure according to the new standards, a trial census will be conducted on the territories of two districts - Obolonskyy (Kyiv) and Borodnyanskyy (Kyiv region).

In 2001, more than 250.000 temporary instructor workers were hired to carry out the census, and in 2020 their number should be reduced to 100.000, mainly due to the introduction of the latest interviewing technologies. Any person who is of legal age and is a citizen of Ukraine can become such a temporary employee.

One of the interesting innovations in new census is that the survey procedure will now be completely anonymous. If the interviewee had to provide complete information including surname, first name and patronymic ealier, then this information will be replaced by the appropriate registration number now.

The current population registration, which is carried out continuously in our country − registration of births, deaths, changes of place of residence, number of emigrants and immigrants, gives an opportunity to see generalized data showing the population in Ukraine in general and in each of region or settlement in particular, as well as general features of gender-age structure and features of its dynamics. The abolition of compulsory residence permits, which took place in 2001, further complicates the ability to control population displacement, migration processes and to monitor demographic dynamics. However, the census will allow us to investigate all demographic phenomena at a much higher level, to identify those problems and contradictions that the current population registration is not able to identify − ethnic self-identification, language skills, property status of the population, the real number of people of retirement age, etc.

The population census questionnaire contains five main sections (modules), which are broken down into paragraphs (Fig. 1).

The planned for 2020 census would include two steps: an online census and a traditional census. The first stage (on-line) will last ten days, during which the respondents have the opportunity to answer the questions of the census form in the personal office of the census site, which is accessed in the presence of the relevant key (Perepys, 2019) .

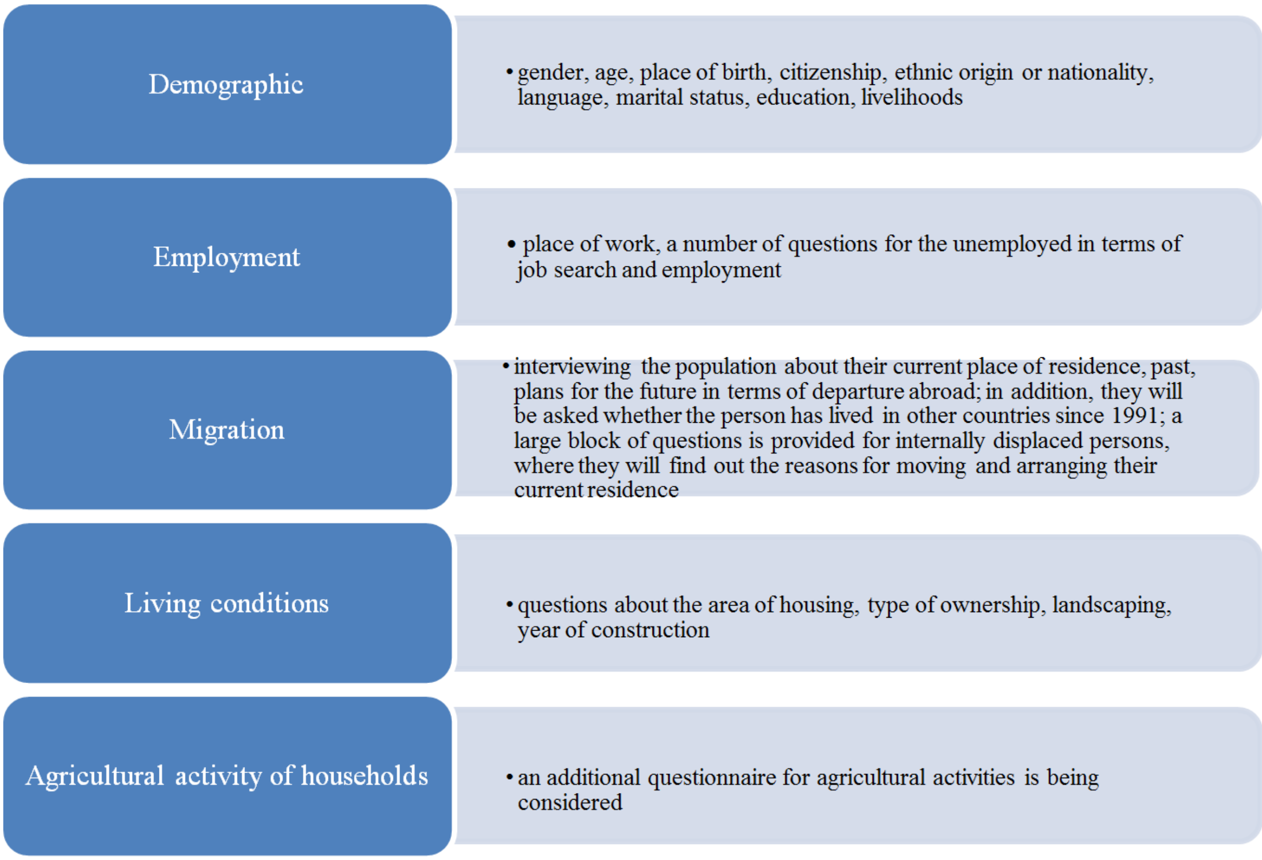

Fig. 1. The main modules of the All-Ukrainian Population Census questionnaire in 2020.

During the second phase, it is planned to visit households by instructors who will provide statistical information on electronic media - tablets and smartphones that will be filled with vector digital maps and GPS navigation, which will allow to read the coordinates of the houses and provide GPS linkage to the map within a certain radius.

The preliminary census in 2001 indicated a number of issues that must be taken into account when conducting the next census:

- the respondents did not understand the individual questions (for example, when it comes to ethnicity, many respondents said that they are nationals of Hutsuls, Lemkies, Ruthenians, etc., not understanding that these categories are parts of one Ukrainian ethnic group – in fact, they are Ukrainians of different ethnographic groups);
- reluctance to answer specific questions, especially those concerning the wealth or income of a person or household;
- providing unreliable data, especially questions about education, property status, language proficiency;
- the inability to identify for themselves and indicate which language is the mother tongue of the respondent in mixed ethnic families. Often, the child has a good command of the language of both the father and mother, so it is difficult to indicate which of them is the mother tongue;
- difficulties in interviewing people belonging to particular religious groups, ethnic groups with a specific culture, who forbid the census, or allow only the male population to census.

Conclusion.

Summarizing the positive and negative trends in conducting online surveys and using SMART technologies during the census in different countries of the world, we can formulate specific recommendations for Ukraine:

1. There is the need to secure at the legislative level the mandatory participation in the census questionnaire (in electronic or traditional form).

2. Having analyzed the Canadian experience, we consider that it would be most appropriate to simplify the procedure for identifying a person when registering for a census. It may be enough to just enter the passport series and number.

3. The positive experience of Brazil demonstrates the benefits of purchasing special equipment – smart phones (or terminals) for the population census

procedure. At relatively low cost, it will be possible to obtain quickly the information, pass it to statistical centers and reduce significantly the time for processing statistical information.

4. The most expedient and effective survey of the inhabitants of the country will be through registration on the web-site of the relevant statistical services. This can be done using a taxpayer ID or a query from the statistics service sent to the respondent's email, which he or she must confirm by clicking the link.

5. The convenience of the Internet census in this case is also that a separate office on the site can be opened for one household. And the data on each member can only be entered by one person at a convenient time.

6. The use of SMART-technologies makes it possible to reach practically the whole population, despite the transport accessibility of the respondent's place of residence, employment and other factors.

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