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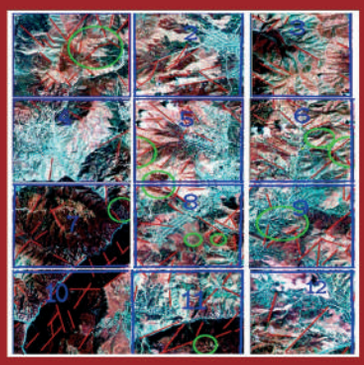

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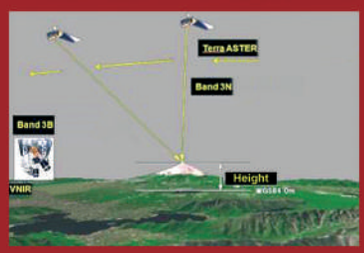

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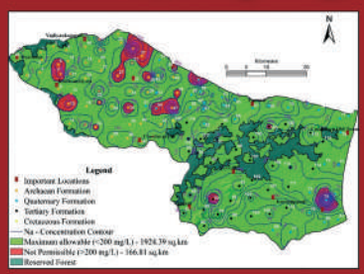

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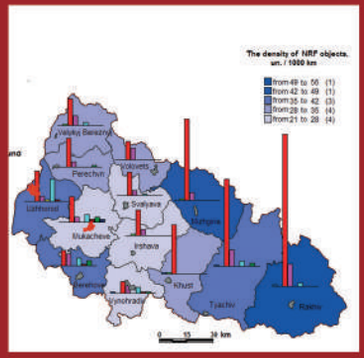

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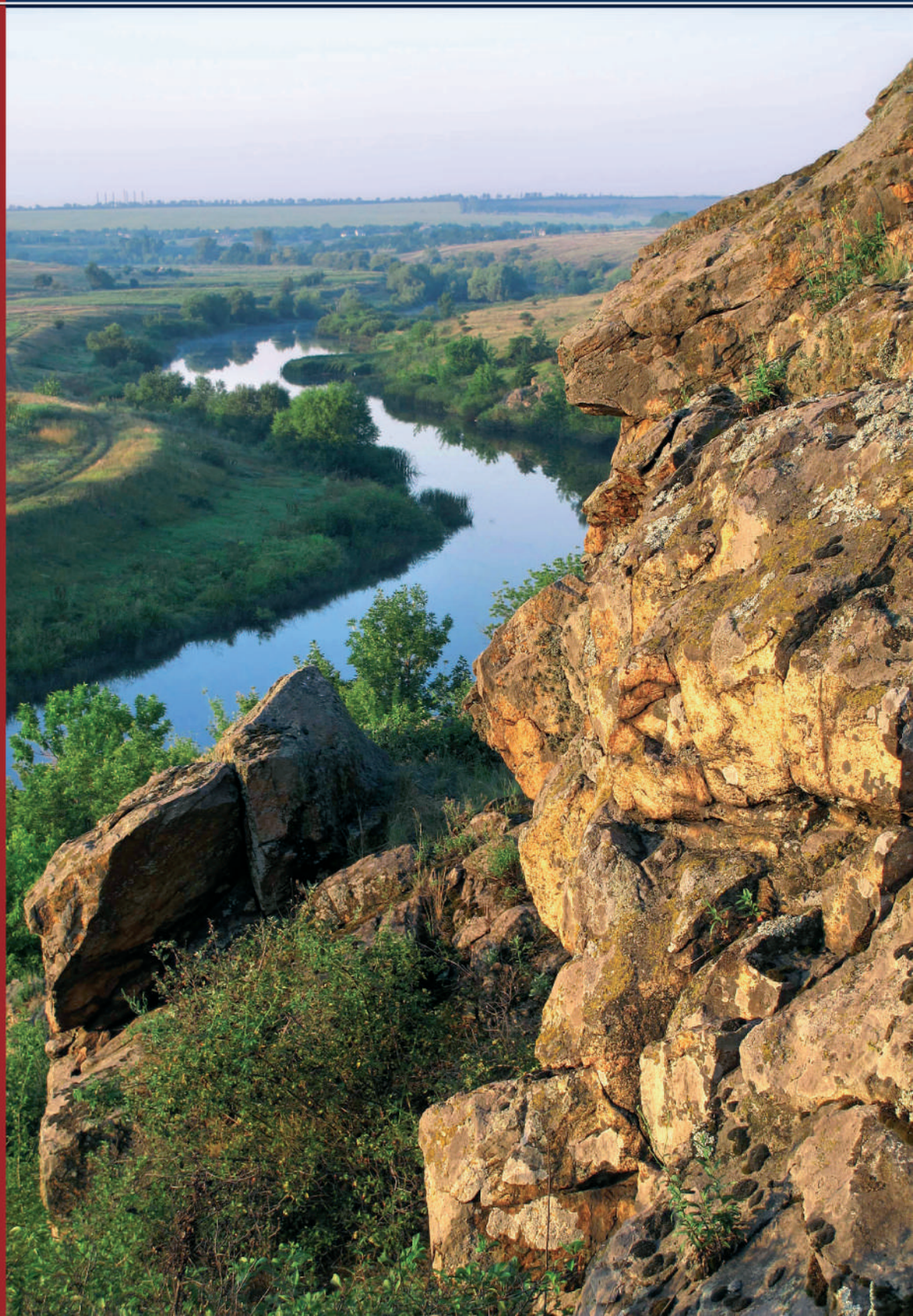

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Theoretical and methodological essence of noospheric geography of the 21st century

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Abstract. In modern conditions of globalization of society development and fleeting transformations of natural processes, when the development of science, including geographical, is extremely accelerated, there is a rapid complication of forms and methods of theoretical and methodological knowledge, which makes it necessary to conduct logical and methodological analysis of geography in modern conditions. It turned out that a hundred years ago, says Edwin Toffler, Thomas Mann put forward a formula that expressed the feeling of death of a certain era. Today, humanity has approached an invisible boundary that separates one era from another. It is established that the world is on the threshold of grand social changes, technical and cultural innovations. In these conditions, when the world has become completely different, it is important for geographers to understand the consequences of the ongoing transformation processes. All this requires a new understanding from the standpoint of a globalized society, to find out what fundamental consequences for geography brought the information technology revolution, which will result in new paradigms for the development of our science. A. Toffler argued in «The Third Wave» that humanity was approaching a new technological revolution, that is, the First Wave (agrarian civilization and the Second (industrial civilization)) was replaced by a new wave that led to the creation of a supra-industrial civilization almost twenty years ago. If the concept of «living matter» (as a natural planetary body) underlies the doctrine of the biosphere, then the selection of such a natural phenomenon on a planetary scale as «scientific thought», becomes the most important naturalistic generalization in the theory of the noosphere. Nowadays, the idea of the coherence of the most progressive social laws and the achievements of scientific knowledge acquires a special meaning, becomes the most important problem of the very existence of human civilization. Based on the above, according to M. V. Bahrov, L. H. Rudenko and I. H. Chervaniov, we argue that «there was a need to create new scientific products that reflect the state and problems of the current stage of development of society», i. e., noosphere geography. The refore, the realization of the purpose of the study is to identify scientific sources about the change of the theoretical essence of modern geography, substantiation of the theoretical and methodological essence of the «new» noosphere geography in the transition of information society to noosphere and clarify the place of noosphere geography in general scientific classification.

Ключові слова: globalization processes, information world, changing the essence of modern geography, substantiation of noosphere geography.

Теоретико-методологічна сутність ноосферної географії XXI ст.

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Анотація. В сучасних умовах глобалізації розвитку суспільства і швидкоплинних трансформацій природних процесів, коли надзвичайно прискорюється розвиток науки, зокрема й географічної, відбувається швидке ускладнення форм і методів теоретико-методологічного пізнання, що робить необхідним проведення логіко-методологічного аналізу стану географії в сучасних умовах. Виявлено, що сто років тому, відзначає Едвін Тоффлер, Томас Манн навів формулу, яка виражала почуття загибелі певної епохи. Нині людство підійшло до небачимої межі, яка відділяє одну епоху від іншої. Встановлено, що світ стоїть на порозі грандіозних соціальних перемін, технічних і культурних нововведень. В цих умовах, коли світ став зовсім іншим, географам важливо зрозуміти, до яких наслідків можуть призвести трансформаційні процеси, що відбуваються. Усе це вимагає нового осмислення з позицій глобалізованого суспільства, з'ясувати які фундаментальні наслідки для географії принесла інформаційно-технологічна революція, які внаслідок цього виникнуть нові парадигми розвитку нашої науки. Е. Тоффлер у праці «Третя хвиля» стверджував, що людство підходить до нової технологічної революції, тобто на зміну Першої хвилі (аграрної цивілізації і Другої (індустріальної цивілізації) прийшла нова хвиля, яка вела до створення надіндустріальної цивілізації. Це було майже двадцять років тому. Сьогодні з'ясовано, що інформаційна цивілізація створила фундамент для народження Четвертої без абзаців хвилі – сучасної ноосферної цивілізації. Якщо поняття «жива речовина» (як природне планетарне тіло) лежить в основі вчення про біосферу, то виділення такого природного явища планетарного масштабу, як «наукова думка», стає найважливішим природничо-науковим узагальненням в теорії ноосфери. Сьогодні ідея узгодженості найбільш прогресивних соціальних законів і досягнень наукового знання набуває особливий смисл, стає найважливішою проблемою самого існування людської цивілізації. Виходячи

із вище сказаного за М.В Багровим, Л. Г. Руденком і І. Г. Черваньовим стверджуємо, що «Виникла потреба у створенні нової наукової продукції, яка відображає стан і проблеми сучасного етапу розвитку суспільства», тобто ноосферної географії. Тому реалізацією **мети** дослідження є виявлення наукових джерел про зміну теоретичної сутності сучасної географії, здійснення обґрунтування теоретико-методологічної сутності «нової» ноосферної географії в умовах переходу інформаційного суспільства в ноосферне та з'ясування місця ноосферної географії в загальнонауковій класифікації наук.

Ключові слова: глобалізаційні процеси, інформаційний світ, зміна сутності сучасної географії, обґрунтування ноосферної географії.

Introduction.

It is established that the contradictions between the new facts in the observations of nature and the properties of a man by special studies and the modern generally accepted picture of the world and its fundamental laws are constantly growing. V. P. Kaznacheiev (1993) clarified that the global desire for unification and convergence of world national technical and religious cultures continues to take shape more and more clearly. In their historical movement, the globe and humanity are entering a new band – the existence of a noosphere society, in which through economic tools will rapidly unite peoples, countries, continents, humanity of the Earth into a single, indivisible, interdependent, cosmic mechanism.

At the same time, according to V. P. Kaznacheiev (1993), the planet Earth, from space view, is like an apple, which is peeled off with a powerful hand, pierced on all sides, eaten by an ugly force, peeled surfaces slowly heal, but not all. Moreover, technical innovations accumulate huge capital, which in the world of privatization, property at any cost trying to buy, to win regional and even global power. In these systems, modern political and state institutions, in fact, no longer play a deterrent role. A new parasitic, socio-political mechanism is also rapidly forming on the planet, which is already confronting and coming into conflict with the existing system of the United Nations of the Planet. State borders retain their own political, in fact, national-political significance. For natural processes (atmospheric, biological, energy, etc.) these boundaries are of no importance, global natural processes have turned out to be uncontrollable. The element of dismemberment and pragmatism leads the Planet, as a cosmic formation, to inevitable chaos. This is the scale of a new psychosocial historical phenomenon of the planet.

Today the main issue of globalization according to M. Senchenko, O. Senchenko and V. Hostynshchykov (2016, p. 55) is to answer the question: who is superfluous on this Earth? To avoid global crises, experts of the Club of Rome proposed to develop a new algorithm (management rules) for the interaction of subsystems (politicians call it a new world order) and to create a central body that regulates their functioning for the benefit of the whole system (World Government). Naturally, the authors continue, in such a situation, nation-states must lose economic and socio-political independence (i. e. lose their subjectivity).

According to their scheme, the development or even the very existence of a number of industries or agriculture in some countries will become impossible, as it will disrupt the optimal functioning of the entire metasystem. In such a situation, the World Government will have to eliminate these industries (and, if necessary, the national economies themselves) to keep the new world order in a stable state. Naturally, these radical measures will primarily affect non-Western countries, whose level of development is disproportionate to Western ones, and therefore will be less valuable for the metasystem (and the authors warn: here is the answer to the question: why Ukrainian industry is destroyed?). It is worth adding another question: why did the Ukrainian government decide to sell the land to foreigners?

Based on the analysis of the current state and opportunities for the development of the INTERNET, INTRANET and EXRANET in foreign sources (Chen, Finin, and Joshi, 2013; ETSI TS, 2013; Gaia, 2014; Gu, Pung, and Zhang, 2004), Lishchytovych, 2019) found out that among a number of powerful global telecommunication networks, in particular reconnaissance and defense, the most widespread is the civil INTERNET, which already performs a number of internet functions in the future Noosphere. Internet users are already accustomed to the appropriate media environment, to audio, video and online games with high resolution, personalization tools for pattern recognition, non-locally tied software, even to security-critical tools such as e-commerce, e-Health, first responders etc. Over the past decade, the number of Internet users has increased thousands of times, for example, in 2017, in just one hour, about 41 million DVDs were sent over the Internet, and video calls accounted for about 85 % of the total Internet schedule. Now almost everything around us is found in the Internet, even the concept of the Internet of Things (LoT). For example, Machine-to-Machine communications (M2M) has already received its own driver to speed up traffic. Also, Voice over IP (VOIP) tools require just over 150 ms for latency, 30 ms for vibration, and about 1 % of packets are lost to maintain optimal Quality of Experience (QoE). Today, the development of Internet technologies is aimed at comprehensively providing people with services packed in the interfaces of the Internet for home life and work, as well as study, recreation, just communication and

more. The author is convinced – this is how the future Noosphere is born.

All this would be wonderful, if there were no thieving actions of the Western authorities. Therefore, Lishchytovych L. I. (2019) notes that already widespread at the beginning of the 21st century, conversations and discussions at scientific conferences on the so-called «sustainable development» of mankind are gradually subsiding due to the falsity of this idea in the agony of world capitalism. Many scientists no longer see a way out, investigating the facts of the rapid death of the basic elements of the Biosphere, which can not recover under the influence of an insane thirst for enrichment of individual rulers. Honest experts, especially ecologists and biologists, have begun to warn of the end of our civilization, along with the destroyed Biosphere.

Other scientists also cite disturbing facts. Thus, Mezhzherin V. A. (1996) found that modern civilization, as a game of chance and law, manifests itself in the form of a disease similar to alcoholism or drug addiction: it gives the illusion of happiness and brings doom to the humanity that has chosen it. Death is determined by many causes, among which two are decisive: reducing the effectiveness of social progress and criminalizing society. The first has the effect of replacing the accumulation of wealth by eating it. The second is the formation of criminal forms of its distribution. Then a period of total lawlessness comes there.

In addition, I. R. Oleksienko and L. V. Keisevych (1997, p. 19, 24) say, an impressive «achievement» is that in the process of civilization, the Earth is transformed into a giant landfill not only simple but also radioactive, sa turated with highly chemically aggressive substances. In fact, the nearby space, the atmosphere, inland bodies of water and rivers, soil, seas and oceans, and the ocean floor have become a «starting point». Every year, about 150 billion tons of liquid, solid and gaseous household and industrial wastes enters this landfill. At least 5 billion tons of human excrements are added to them annually from the six billion population of the Earth, which even existing treatment facilities cannot cope with neutralization, not to mention natural detoxification systems. It is should be supplemented with the annual movement for the extraction of minerals using up to 15 km^3 of soil, of which only 7 % is used for the manufacture of the final product. As a result, we have a clear and undisputed conflict in the relationship between man and nature.

Oleksienko I. R. and Keisevych L. V. are convinced of this: only a small part of the most obvious tasks that humanity needs to solve without denial in the 21st century, if, of course, it wishes and, most importantly, has time to do so until power over the world is passed completely into the hands of organized crime, and the octopus of civilization is generated by mankind with its tentacles did not suffocate in the arms of the biosphere and man-made.

Kaznacheiev V. P. (1993) stated that in these conditions, the very forces of the scientific and technical global process in the late twentieth century were in the hands of a new, far from humane, system of power. It is necessary to ask, who investigates all this new historical dynamism of mankind of the planet? What is a scientific organization or association of scientists and practitioners? Real experience suggests nothing.

Today, the idea of the coherence of the most progressive social laws and the achievements of scientific knowledge acquires a special meaning, becomes the most important problem of the very existence of human civilization. The authors agree with the opinion of scientists – M. V. Bahrov, L. H. Rudenko and I. H. Chervaniov (2010, a), who found that there was a need to create new scientific products that reflect the state and problems of the present stage. Development of society is the transition of the Biosphere to the Noosphere and the creation of noosphere geography. In the transition of the Biosphere to the Noosphere, the problem of new knowledge – noosphere geography is exacerbated as a practical and social problem. Philosophical understanding of the results of modern development of noosphere-geographical ideas is a necessary condition for a correct understanding of the laws of science in the modern world, its place in social progress. Science and education will play a fundamental priority role in the process of transition from the biosphere to the noosphere.

Research methods.

The authors conducted research in accordance with philosophical principles: objectivity of content, historicism, the contradiction of the process of cognition. Disclosure of the full depth and richness of the content of the principle of development is possible only on the basis of consistent implementation of the dialectical approach, which contributes to the general generalization embodied in specific forms, interconnected in accordance with the structure of interaction of categories «general», «special» and «separate». The methodological essence of the study is based on the philosophical and concrete-philosophical levels. It is pplied: *the method of inference knowledge*, which is due to the process of obtaining *review information as inference knowledge*, which is derived by purposeful logical justification; *ascending method* from abstract to concrete; a *systematic approach* in considering a single system of forms of motion of matter in conjunction with the theoretical and methodological justification of noosphere geography; *literary source, historical and classification method*. The general procedures of regularities of cognition are

also taken into account: *predication* – a logical act of establishing the properties of the object under study; *constructivization* – a way to include the studied position in the system of the whole in the form of a meaningful system of obtaining new consequences; *application and interpretation* as ways to reveal the new in knowledge through its addition to new areas of activity.

Materials.

Nowadays, there are more and more calls from humanity and scientists to develop theoretical and methodological issues for the development of the Noosphere and justify the mechanisms of transition to the Noosphere – the realm of reason and justice. These appeals compel us to trace first of all the history of the very notion of the «noosphere».

Summarizing the accumulated knowledge about the shell («spherical») structure of the planet Earth, the Austrian geologist Eduard Susses (1909) in a three-volume work «Face of the Earth» outlined the «synthetic concept of geospheres», identifying three material shells: solid (top is sedimentary) – stratisphere, water and air. From the 17–18 centuries there were known the ideas about the relationship of inanimate and animate nature. For example, the British scientist John Woodward in his work on natural history wrote about the role of living organisms in geological processes, and the philosopher Jean-Batiste Pirre Antoine de Monet, Chevalier de Lamarck (1802) expressed the idea of the planetary role of life, noting the significant role of living organisms in changing the Earth's crust. V. M. Corsunov and E. N. Krasekha (2010, p.13) note: Lamarck emphasized: «Complex minerals of all kinds, which form the outer crust of the Globe and occur there in the form of individual clusters, bodies, parallel layers that form lowlands, hills, mountains, are exclusively the product of animals and plants that existed in these parts of the Globe».

The famous German naturalist Baron Friedrich Wilhelm Heinrich Alexander Freiherr von Humboldt (1862) in the fifth volume of the «Cosmos – Entwurf einer physischen Weltbeschreibung. E. I. Kolchynskyi» (1990, p. 7), emphasizes that O. Humboldt in this work already characterizes a certain sphere of life, which he called «life sphere» as a regular in the form of a specific Earth's shell and an inseparable part of the Earth's surface, where a single integral system of atmospheric, marine and continental processes, as well as wildlife phenomena.

In The Origin of the Alps (Die Enstehung der Alpen), E. Süss (1875) singled out of all the Earth's crust, a special living shell, the biosphere, which stretched in the surface geospheres and was formed by the living inhabitants who inhabited it. Under the biosphere E. Süss understood the Earth's shell (geosphere), inhabited by living beings, and not the totality of living beings.

In 1922–1923, while V. I. Vernadskyi was lecturing at the Sorbonne in Paris, he adopted biogeochemical phenomena as the basis of the biosphere. Some of these lectures were published in «Sketches of Geochemistry», which was first published in French in 1924, and in 1926 – in Russian. In 1927, E. Le Roy (1927), a French mathematician and philosopher – Bergsonian, adopted the biogeochemical basis of the biosphere established by Vernadskyi V. I. as the source and in his lectures at the Collège de France in Paris he identified the «intellectual and spiritual layer», where his opinion, correlated with the evolution of the brain and received a special impetus to expansion in the biosphere with the advent of man in it. He substantiated the formation of the «spiritual layer of life», which was defined by E. Le Roy as the «noosphere» (the first use of this term).

In turn, Marie-Joseph Pierre de Chardin (1987, pp. 148, 150) investigated that under geochemical, geotectonic, geobiological pulsations there is a deep process – the one that materialized in the first cells, continues in the creation of nervous systems. He proved that geogenesis transitions to biogenesis, which ultimately is nothing more than the psychogenesis that led us to man. Now, he notes, psychogenesis changes and is absorbed by a higher function – first by origin, then by the development of the spirit – noogenesis. To the four overlapping shells of the Earth since the time of E. Süss, science adds a living film formed by the plant and animal surface of the globe – a universal shell – the Biosphere. Around the spark of the first reflective consciousness, according to Pierre de Chardin, a fire began to ignite. The flames eventually engulfed the entire planet. Only one name has the ability to express this great phenomenon – the Noosphere. Just as extensive and much more complete than all the other previous covers, it is really a new cover, the «thinking layer» that emerged at the end of the Tertiary period (during the Paleogene and Neogene -– B. C., I.D.), has been unfolding ever since over the world of plants and animals – outside the biosphere and above it. A new era begins, the Earth «changes the skin». Moreover, it receives the soul. The most careful researcher of our modern science can find here that everything is valuable, everything is progressive, from the beginning present in the cosmic rag from which our world came, is now concentrated in the «crown» of the Noosphere.

Already in our time, Paul R. Samson and David Pitt (2002), based on numerous sources of Western scientists, analyzed the development of the concept of «noosphere» from its origins to the present and suggested that the two concepts – biosphere and noosphere are interdependent. Early promoters, they note, of the concept of the noosphere – Teilhard de

Chardin, E. Leroy and V. Vernadskyi considered the noosphere, albeit in different forms, but as a natural extension of the physical nature of the biosphere. It is important to recognize that they define and develop the role of human society in the biosphere, which has an extraordinary planetary role of consequences. The concept of the noosphere is clearly based on the classical geology of the representation of the Earth as a sequence of concentric spherical shells: barisphere, lithosphere and biosphere, first described in the work «Face of the Earth» (Das Antlitz der Erde) by Austrian scientist Eduard Süss (1875; 1909). The noosphere as a higher sphere subordinates other spheres, but develops together with other spheres.

During the first decade of the 20th century, the authors continue, they began to clearly define the role of humanity as the dominant geological force on the planet. J. Parkins Marsh, Edward Suess and others. began to view humanity as the potential to change the face of the Earth on a global scale. J. P. Marsh argued that man is a new telluric force, which in strength and universality can be compared with the great forces of the Earth (Cited by: Ckark and Munn, 1986. 10). Paul R. Samson and David Pitt (2002) note that it is important to note the key differences between the conceptualization of Teilhard de Chardin, E. Leroy and V. Vernadskyi. For the first two, the noosphere is seen as an irreversible phase of biosphere development – a predetermined process driven by the phenomenon of a man with the noosphere as a kind of evolution of the stage outside the biosphere. In essence, they viewed the biosphere as an intermediate step leading to the higher plane of the noosphere present in their work at an early stage. For V. Vernadskyi, the biosphere was the basic principle of life, and the noosphere was rather a part of human potential and a stage of its development. For V. Vernadskyi, the biosphere and noosphere are interconnected in the framework of the coevolutionary development of the process. In any case, without the biosphere there could be no noosphere, no matter how one defines last one. Teilhard de Chardin created a comprehensive scientific and pantheistic concept of Noogenesis (1987, pp. 24–35).

Paul R. Samson and David Pitt (2002) emphasize that at the United Nations Conference on the Environment in Stockholm in 1972, many reports stated that the biosphere should be seen as a fundamental concept of life on Earth, covering the development of people to the environment. The authors note that the development of biogeochemistry has its roots in the work of V. Vernadsky and today the study of «Biogeochemical cycles» has become an active field of science that promotes research by a group of scientists from the Scientific Committee on Environment (Bolin and Cook, 1983) and ask: «Why this concept and the reference to the idea of the noosphere has received so little attention and even recognition until the mid-1980s?»

Hilarov (1995, p. 193) notes: «Probably not by accident with the approach by the end of the 20th century the work of the scientific community of scientists such as Polunin (1982), Clark and Mann (1986), Grinewald (1987; 1988) and Haggett (1995) was particularly useful in popularizing the idea of the noosphere. Works such as «What is life?» (Margulis and Sagan, 1995) and «Cycles and Life: Civilization and the Biosphere» (Smil, 1997) have paid considerable attention to these same issues. Moreover, this probably indicates the changing times, which were influenced by the main contribution of V. Vernadskyi – the work «Biosphere» – was first published without abbreviations in 1988 with a foreword by prominent scientists presented by microbiologist Lynn Margulis. According to Lynn Margulis and Dorion Sagan, V. Vernadskyi showed that all life lived materially in a single place – the biosphere. V. Vernadskyi portrayed life as a global phenomenon in which solar energy was transformed (1995, p. 47).

Paul R. Samson and David Pitt (2002) found that during the Cold War, Vernadskyi's work was occasionally distorted by jealousy and competition, as Soviets often outnumbered Americans in space. The French natural philosopher Jacques Grinewald (1998) compared Vernadskyi's slow recognition of Thomas Kuhn's notion of the «invisible» scientific revolution. This analogy seems particularly relevant as the concept of the biosphere is increasingly recognized as the most important idea in thinking about global environmental change.

Paul R. Samson and David Pitt (2002) found that regardless of worldview, the noosphere is an important phase in the history of our planet. Importantly, the noosphere is an unprecedented event: Earth and society seem to be entering a critical period at this stage. In many ways, the Earth has become a single system intertwined with the interconnections of global reason and global action. Again, we were faced with two questions: what direction does public opinion want to move into the noosphere, and in what directions can the noosphere go? In practice, and in today's world, this means asking how the noosphere can be used to address issues such as the environment, health, poverty, violence and inequality.

Before moving on to these issues, Paul R. Samson and David Pitt (2002) offer several basic views on the noosphere:

1) an optimistic view of the noosphere is essentially related to concepts irreversibility and inevitability. It is believed that humanity is moving to a higher level of existence and this progress does not stop;

2) it would seem that the second optimistic view will support the same concepts or at least not deny them, although the driving force is not the spiritual energy, but there is human creativity in the form of technology;

3) shares a positive view of science, technology and human potential, but remains fundamentally tied to the constant physical limitations of the biosphere. From this point of view, humanity needs to design appropriate ways to govern the world, and all will be well;

4) provides for the possibility of balance between the biosphere and noosphere, but draws attention to the inherent unpredictability, which is manifested in human progress.

V. Vernadskyi's concept of the joint evolution of the biosphere and noosphere and his opinion that people are free to develop their future, albeit unpredictable. According to Eccles and Popper (1990) the idea of the noosphere needs good news as well as the fundamental role of intelligent matter, or perhaps another quantum process (Penrose, 1995). In particular, there are many opportunities in living matter to capture and justify the patterns of development of Nature in interaction with the development of society. As Lynn Margulis and Dorion Sagan point out (1995, p. 138): «The noosphere is still in its infancy», but «perhaps now at the most impressive stage». Indeed, it seems that this is the time of the most important decisions for our future. The authors believe that this time has come.

It was at the beginning of the twentieth century. V. I. Vernadskyi (1988) noted: two great facts, before which all others seem almost smoothed, prevail in the history of the Earth's past: the revival of matter and the humanization of life. Within living matter in the last decade, a new form free energy – biogeochemical energy, which covers the entire biosphere and determines mainly its history. This new form of biogeochemical energy, which can be called the energy of human culture, is the form of biogeochemical form that creates the noosphere in our time. We are just experiencing its bright entry into the geological history of the planet. Under the influence of scientific thought and human labor, the biosphere passes into a new evolutionary state – the Noosphere. **The creation of the biosphere and noosphere is a natural phenomenon, deeper and more powerful at its core than human history. It requires the manifestation of humanity as a whole** (highlighted – B. C., I. D.). This is its inevitable precondition and a new stage in the history of the planet, which essentially creates something new in the history of the Earth. Scientific thought as a manifestation of living matter carries the possibility of unlimited development over time perhaps billions of years, the process of creating Homo sapiens Faber is *not a short-lived and fleeting geological phenomenon*. Processes that have been prepared for many billions of years cannot be fleeting, they cannot be stopped. It follows that the biosphere will inevitably pass one way or another, sooner or later into the noosphere. Forming the noosphere, the biosphere has all its roots in the earth's crust, something that has never been seen before in human history. The main geological force that creates the noosphere is the growth of scientific knowledge. Scientists face for the near future an unprecedented task for them to consciously direct the organization of the noosphere, from which they can not move, because it directs their spontaneous growth of scientific knowledge (Vernadskyi V. I., 1988). Under these conditions, as V. I. Vernadskyi noted, «The biosphere of the 21st century is transformed into a noosphere, which is created primarily by the growth of science, scientific understanding and social work of mankind based on it» (Vernadskyi, 1977). Vernadskyi V. I. in his work «Scientific Thought as a Planetary Phenomenon» noted: «It is now necessary to take into account circumstances that have never existed in human history to such an extent. Everything that is experienced cannot be long and lasting, and the transition of the biosphere to the noosphere that we are experiencing cannot disappear». He continued: «In the noosphere, the spiritual life of the human person is strong and decisive, in its social manifestation» (Vernadskyi V. I., 1988). These considerations of V. I. Vernadskyi was inspired by Academician I. P. Herasymov at the coordinatory meeting of geographers to call one of the main tasks of constructive geography the development of an extensive interdisciplinary program for the transformation of the Earth's biosphere in the twentieth century into the noosphere of the 21st century, outlining 12 points of the program (Herasymov, 1986).

It was found that V. I. Vernadskyi, observing the beginning of the scientific and technological revolution, believed in the human mind and its unlimited possibilities, and therefore was confident in a fairly rapid transition of the biosphere to the noosphere. V. I. Vernadskyi (1977, p. 133) in the early twentieth century confidently wrote: «I look forward very optimistically. I think that we are experiencing not only a historical, but also a planetary break. We come to the conclusion about the transition to a new social order, a new era in human life and life on our planet in general, when accurate scientific thought as a planetary force comes to the fore and changing the whole spiritual environment of human societies, when it embraces and changes the technique of life, artistic creativity, philosophical thought, religious thought. I am deeply convinced, and I am increasingly convinced that the only way to make social culture strong is to raise the masses, to make for them, culture (especially science) is vital… We live in the transition to the Noosphere».

However, according to Abramov L. S. (1988), for many years the name of V. I. Vernadskyi was not mentioned in the press or in university courses. He was not properly assessed by some compatriots (for example, A. I. Oparin). Moreover, whole generations of scientists – biologists, chemists, geographers worked in the fields close to the work of V. I. Vernadskyi, not knowing the basic works of his great compatriot.

V. I. Vernadskyi (1988) at this time was convinced that all mankind was taken together, but with his brain. In the geological history of the biosphere, a man has a great future, if he understands this and will not use his mind to self-destruction. The historical process is radically changing infront of our eyes. For the first time in the history of mankind, the interests of the masses, on the one hand, and the free thought of the individual, on the other, determine the life of mankind, are the measure of justive ideas. Humanity as a whole is becoming a powerful geological force. And before him, before his thought and work, is the question of *restructuring the biosphere in the interests of free-thinking humanity as a whole*. This new state of the biosphere, which we are approaching without noticing it, is the *noosphere*.

His general works have been published relatively recently. Even the «Chemical Structure of the Earth's Biosphere and its Environment» (the main book of life, according to the scientist himself) was published only in 1965–20 years after his death. The publication of other works, starting with the «Notes of a Naturalist» was delayed for another 10 years. Many scientists, realizing the process of transition from the biosphere to the noosphere, began to study actively his works and develop new ideas in the last quarter of the 20th century.

Having established the patterns of development of society and science in the late twentieth century, M. V. Bahrov (Bahrov M. V., 2005) specified that a shock more cardinal because of the speed of its origin, was the information age. The concept of information space also appeared. A total corporate-network market was formed, which covers all forms of socio-economic, spiritual and other spheres of life. The network in the information society has become the circulatory system of the world economic organism. Thus, for the first time in human history, we are dealing with a purely noosphere process, which determines the basis of human existence, because information and communication are intangible substances of the new world. Informatization and globalization have turned most of the world into a single system and set science the task – to formulate such system-wide laws that would reveal a number of patterns of formation of a new world order. Alvin Toffler (Toffler, 2004) described the patterns of global change: **the world is on the threshold of great social change, technical and cultural innovations**. The profound and impressive development of the potential of technology will have an impact on all aspects of social life. Microelectronic evolution increases the power of human intelligence. Technological innovations will have an impact on the social structure of society. In fact, a new way of civilization is born, in which the sphere of work, management, and recreation will be fundamentally different. Mankind is entering a new era – the era of existence of man and society in a fully **technical and informatized world of the noosphere**. The conflict between the groups associated with the Second and Third Waves of Science is in fact the central axis of political tension along which our society is divided today. **The sooner humanity realizes the need to move to a new third wave, the less there will be threats of violence, dictatorship and other troubles** (highlighted by the author). Korchak K. (2008) found that with the transition of society to the noosphere environment of the XXI century society will not be informational with the mass spread of personal computers and the Internet, but a society of **nano-, pico- and frame technologies** that will replace all sectors of employment and will require for its emergence and use significant changes in education systems, including the transition from elite university to general and multisectoral higher education.

The influence of modern development of society on geography, which appeared at the beginning of the «revolution in the system of scientific worldview as a search for a noosphere model of future humanity in the 21st century, which covers *all sciences and all spheres of continuing education, as a leading problem of noospherogenesis*» (Subetto, 2009).

Results and their analysis.

The regularities of geography development in the conditions of mad influence of informatization of society are characterized, although geographers in the last quarter of the 20th century believed that the «filled» territory is our object of study, – M. V. Bahrov (2008) said, – and approached its analysis as a geosystem, where real material and energy flows functioned, materialized energy production cycles. Now a new world has opened infront of us, built on a qualitatively new information basis to understand and know the global world is possible only by studying its various dimensions. The author is convinced that this dictates the emergence and development of the latest branches of knowledge – **geoeconomics, geofinance, geoinformatics, geoecology, geoculture**. The information age began to influence geography, forcing it to delve into the object of knowledge with a different, more modern measure, with a deeper understanding of geospace, its immanent properties, with knowledge not so much real as a virtual network, a different assessment of resources when material values are replaced emerging intangibles. After all, today's production system of

the world seems to «breathe», flows from one region to another, the world of industry is largely becoming virtual and managed by managers. Based on the fact that the immediate and most important task of geography will be to identify virtual dynamic forms of information as an object, object and means of production, it can be argued that this will deal with **information geography** (Bahrov, 2008; Rudenko, 2006).

Bahrov N. V., 2008 and Rudenko L. H., 2006 found that the global development of society and science shows – the era of civilization «Third Wave» A. Toffler – the era of «information society» is coming to an end, preparing a strong foundation of the «Fourth Wave» – «noosphere society» with the newborn «noosphere geography». There are all grounds for this in Ukraine: in the last decade the works of M. V. Bahrov, L. H. Rudenko and I. H. Chervaniov have been published, which are a guide for substantiating the future development of geographical science in modern conditions of the beginning of noospherogenesis (Bahrov, Rudenko, Chervaniov, 2010; Bahrov, Rudenko, Chervanov, 2010; Bahrov, 2011). The right opinion of M. V. Bahrov about the movement of modern geography to the socioospheric direction of development was also expressed. It is revealed that the first characteristic of «noosphere geography» at the end of the 20th – the beginning of the 21st century in Ukraine is associated with the names of the famous geographers: Bagrov N. V., Rudenko L. H., Chervanov I. H. They found that in the 21st century «there is a powerful, irresistible process of informatization of society infront of our eyes, the world is rapidly becoming different. Already today, a third of humanity communicates via the Internet, the virtual world has become for many people a kind of «second entity». Since we are all also in this stream of transformational changes of the «third wave» of world civilization, we do not even realize that each of us, without noticing it, already lives in the informational world. World business is moving in the stream of information technology and rushing in it, accelerating the pace by tens of percent per year. M. V. Bahrov and co-authors emphasize: «The current production system of the world seems to «breathe», flowing from one region to another, the world of industry largely becomes virtual and managed by managers – this is **information geography**» (Bahrov, 2008; Bahrov, Rudenko, Chervaniov, 2010; Bagrov, Rudenko, Chervaniov, 2010). Today there is an urgent need for a positive perception of the need facing geography: **to intensify their participation in business, creating business geography** (Chervaniov, Ihnatiev, 2008).

M. V. Bahrov found out that geography today faces a fateful question: will it agree with the secondary role as a science and school discipline or can become an equal member of the scientific community on the highways of scientific and technological progress and fit into the evolutionary process of the information society? We must be prepared for the fact that the geographical space, which is the object-subject foundation of geography, will be gradually replaced by the information space. Based on the above, he stated: «Information about the environment of mankind – the process of noospherogenesis, requires multidisciplinary scientific support. It becomes clear that we are on the verge of the emergence of a new branch of our science –sociospheric geography» (Bahrov, 2011). And immediately cited the scientific «attributes of sociospheric geography». All this suggests that geography is becoming different in its object-subject essence. But will it happen?

The regularities of the development of noospherogenesis and the formation of noosphere geography are characterized, which will unite the emerging information and socioospheric geography, and need to determine its place in the system of natural and social sciences. The authors of noosphere geography M. V. Bahrov, L. H. Rudenko and I. H. Chervaniov outlined a preliminary way to solve this problem, but it remained incomplete (due to the premature transition of the genius geographer M. V. Bahrov – in another world) and therefore the continued existence of noosphere geography was open for a long time. It is believed that the solution to this question should begin with the main thing – with the classification of natural sciences, which will determine the place of noosphere geography in the system of these sciences.

It is found that today the objectively fundamental basis for the classification of sciences is the classification of forms of motion of matter, substantiated by F. Engels: «Classification of sciences, each of which analyzes a separate form of motion or a number of combined, which each pass into another form of motion, is at the same time a classification, location, according to their inherent sequence, it is these forms of motion, and this is its significance. Transitions must be carried out by themselves and be natural. Just as one form of movement develops from another, so the reflection of these forms, the various sciences, must necessarily flow from each other» (Engels, 1982). F. Engels compiled the following hierarchical series of forms of motion of matter: **mechanical, physical, chemical, biological and social**. Today, as (Bazaluk, 2014) notes, scientifically proven legitimacy of the transition of some forms of motion to other more perfect forms of the structure of matter, types of interaction (relationships) between the structures of matter and habitats. It is established that evolution is not just a complication of the material world, but a complication of the named structures, that it is a continuous process of *self-complication* caused by derivative activity, which is the basis of evolution as its cause. The regularity of evolution is

characterized – there is *not a linear complication, but a branched process* and complication of the structure of matter, types of interaction and habitats, in which each element is part of the previous element and simultaneously includes all subsequent elements. Such a nonlinear hierarchical complication of the structure of matter, types of interaction and habitats is a *directed evolutionary process*. The development of the complication of the structure of matter, types of interaction and habitats according to the law of dialectics is estimated: «Movement and development in nature, society and thinking are due to the bifurcation of the one into interpenetrating opposites».

It is established that the classification of sciences by forms of motion of matter is fundamental for the current stage of the development of science, which allowed B. M. Kedrov to substantiate the idea of divergence in the development of nature into inorganic and organic (Kedrov, 1962; Kedrov, 1985). As it turns out today, the divergence of natural development began with the emergence of life on the Earth planet, «i.e. 4.252 billion years ago» (Nemchin, Whitehouse, Menneken, Geisler, Pidgeon, Wilde, 2008). Two branches diverge from the chemistry: «the branch of organic chemistry leading through biochemistry to biological beings, and the branch of inorganic chemistry leading through crystallography to mineral formations». (Kedrov, 1961; Vasilieva, Orlov, 1983). It has been established that such branching was prepared at the atomic level of the structural organization of matter» (Kedrov, 1972). These branches after the divergence of the chemical form of motion of matter correspond to the geological and biological forms of motion of matter. In this case, «geological form of metter motion acts as a necessary condition for the active evolution of matter – the formation of life (living matter)» (Moroz, Onopriienko, Bortnyk, 1997; Zubkov, 1979). Thus, the classification of forms of motion of matter has become nonlinear, but which more adequately reflects the ratio of forms of motion of matter in nature.

It was found out that the development of inanimate nature (inert matter) at the *stage of the geological form of motion of matter is not completed*. This was noted by F. Engels in the section «*Physiography*»: «After the transition from chemistry to life, we must first consider the conditions in which life arose and exists – hence, first of all, geology, meteorology and the rest. And then the various forms of life, which without this can not be understood» (Engels, 1982). Liamin V. S. notes that the idea of the existence of an independent geographical form of motion of matter belongs to A. A. Hryhoriiv. He considered it a way of existence of the geographical shell as a special material system on which there was no life from the beginning. According to him, the geographical form of motion of matter is a dialectical unity of interconnected and transitional climatic, hydrological and geomorphological processes. In the future, they are connected to the biological form of motion of matter. A. A. Hryhoriiv developed the idea of a unique global process, which covered the near-surface layers of the planet, as a special form of motion of matter – geographical. This was a fundamental natural-historical generalization. But this problem at that time (1932) was not the focus of philosophy, and A. A. Hryhoriiv failed to avoid some methodological errors that called into question the validity of the very concept of the geographical form of motion of matter (Liamin, 1984). Based on dialectical criteria for the selection of forms of motion of matter, the data of in-depth analysis of the concept of geographical form of motion of matter V. S. Liamin clarified the selection of forms of motion of matter on the basis of such criteria, «as the presence of self-developing system laws and science, the presence of genetic and structural links with the lower form of motion of matter, the presence of specific forms of space and time and a specific form of reflection» and concluded that «the development of inanimate nature on the Earth does not end at the level of geological organization of matter higher for inorganic nature is the geographical form of motion of matter» (Liamin, 1978; Liamin, 1984). This means that, starting with the chemical form of motion of matter, the development of inanimate nature on Earth after divergence is two consecutive series: in the first, each form of motion of matter «naturally generates a higher form: **physical – chemical – geological – geographical**. In this series, the geographical form of metter motion follows the geological one, as the highest of the known forms of motion of matter in inorganic nature» (Liamin, 1978). The second series has the following successive changes in the forms of motion of matter: **physical – chemical – biological – social**. It is proved that the appearance of man meant the emergence of a special, qualitatively new in comparison with all previous types of movement and development of matter – the social form of movement (Belyk, 1982). Describing political economy, F. Engels in his work «Anti-Dühring» described the economic form of motion of matter. Marakhov V. H. argues that society, the system of subjects and the individual are defined as a system of relations that express the qualitative specificity of the social form of motion of matter (Marakhov, 1984). This was confirmed by other scientists, which gave reason to talk about the socio-economic form of motion of matter (Syrotenko,, Chernov, 1991).

In significantly changed conditions in society, new learning conditions are needed. This was eloquently stated by Toffler A. (1997), who using a huge social prognostic resource based on interpolation and prediction came to the conclusion that what

was studied in schools and universities called «a hopeless anachronism». All educational institutions, in his opinion, are moving with their heels forward to a system that is already completely obsolete. Their energy is focused on training Industrial People, people committed to surviving in a system that will cease to exist before they do. The challenges of tomorrow require not millions of superficial people, not people who follow instructions without batting an eye, but people who can find their way in a new environment, who will quickly adapt to new relationships in a total market. The people of the future will need *new skills in three critical areas – lifelong learning, productive connections and choice*.

Based on the expected significant changes in the content and position of geography in the future noosphere society, the authors previously substantiated the noosphere form of motion of matter as the highest form of motion, which unites all other forms of motion into a single whole, which will explore noosphere geography. The classification of forms of motion of matter is, according to F. Engels, the basis for the classification of natural and social sciences (Fig. 1), where the noosphere form of motion corresponds to noosphere geography with developed by M. V. Bahrov attributes that correspond to the modern global information society became a fundamental concept of geographical space, replaced by network space and territorial organization.

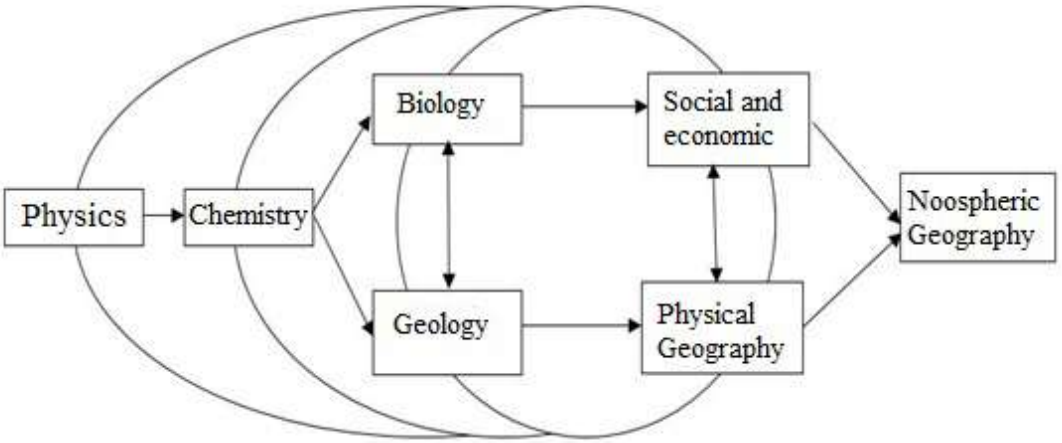

Fig.1. General classification of sciences

Intangible lies in the basis of the functioning of world networks, but all the more impressive in its power process of information exchange; pushing material values into the background and reducing to absolute intellectual and innovative «breakthroughs» the hitherto unknown «players» of the world intellectual market. All this should form the concept of noosphere geography, which radically changes its content along the entire vertical of its internal structure – from object and subject to place among the social sciences and place in the modern world» (Bahrov, Rudenko, Chervanov, 2010). Information about the living environment of mankind – the process of noospherogenesis requires multidisciplinary scientific support. The above gives rise to the idea that humanity is at the beginning of the emergence of a new science – *noospheric geography*, which agrees with the three challenges of humanity – the process of noospherogenesis requires multidisciplinary scientific support. The above gives rise to the idea that humanity is at the beginning of the emergence of a new science – *noospheric geography*, which agrees with the three challenges to humanity justified by Bahrov M. V.:

1) with the extraordinary ecological transformation of the Planet; 2) with threatening tendencies of moral birth; 3) with the growth of the population of the planet and the deepening of the social polar polarization between the adapted (prosperous) and unadapted parts of humanity. Today, we are on the verge of losing a single universal perspective, splitting the world into a «golden billion» and the rest of the world's impoverished population. Today, as never before, the question is acute – what ways can lead us to a qualitatively new society. Participation in this noosphere geography can not be overestimated.

It was found that the formation of the noosphere, according to V. I. Vernadskyi, is a new postbiosphere reality. According to M. V. Bahrov, L. H. Rudenko, I.H Chervaniov, the object of noosphere geography should be an integrated resource for the development of society (society), which is the territory in a comprehensive global scientific vision and pragmatic perception of

humanity, which is aware own goals and opportunities for development. Forms of organization will be: cores, servers, information networks and the conscious attitude of people. Territories are characterized by natural and socio-economic properties, which together and in a systemic combination are natural-socio-economic capital, constituting the *integral potential of the territory*. Then the goal of noosphere geography will be to form a noosphere of a new postbiosphere reality with the study, inventory, ensuring the rational use and conservation of geosystems and natural and social capital, because this is the only prerequisite for self-sustaining human development in terms of conservation and rational use (Bahrov, Rudenko, Chervaniov, 2010). The objective component of noosphere geography is information and socioospheric geography. It should be emphasized that the implementation of all the proposed ideas will depend on the level of development of the content of noosphere geography and the formed consciousness of people. It was found that it is necessary to set in motion the intellectual forces of the geographical community, which would be ready to accept the challenge of time with giving a real constructive meaning to the noosphere geography.

Conclusions.

It is established: in the conditions of transition of information society to noospheric the regularities of substantiation of theoretical and methodological essence of noosphere geography of the 21st century in terms of formation of noosphere society are characterized and its place in the system of natural and social sciences is clarified. It was found that the theoretical and methodological substantiation of noosphere geography is the awareness of the noosphere as a new geological phenomenon on our planet, which noosphere geography will study. This uses a deductive research strategy, in which the analysis of the scientific literature and their own understanding that the *noosphere* (according to V. I. Vernadskyi) – is the last of many states of evolution of the biosphere in geological history – it is the state of our time. Not only the development of the transformation of human society, but also a conscious, systematic re-transformation of nature and the geographical environment as a whole is rational for noosphere. Noosphere geography, really reflecting the real world, scientifically accurately analyzing the interaction of nature and society will accurately predict the development of the geographical environment under the influence of intelligent society.

In significantly changed conditions in society, new learning conditions are needed. It is found out: Toffler A. (1997), using a huge social predictive resource based on interpolation and prediction. He concluded that what was studied in schools and universities he called «a hopeless anachronism». All educational institutions, in his opinion, are on the heels of a system that has already become obsolete. Their energy is focused on training Industrial People, people committed to surviving in a system that will cease to exist before they do. The challenges of tomorrow require not millions of superficial people, not people who follow instructions without batting an eye, but people who can find their way in a new environment, who will quickly adapt to new relationships in a total market. The people of the future will *need new skills in three critical areas – lifelong learning, productive connections and right for choice*.

With a scientifically sound organization of the educational process, «Noospheric Geography» becomes an advanced system of education for future citizens of the country and desirable for adult citizens, ahead of other areas of social activity, as information processes will be ahead of material and energy. Noospheric geography in the formation of noospheric society to preserve the aspirations and traditions of the national high school. According to Ursul A. D. (2014), the process of futurization of education will develop to form a leading human consciousness, able to both predict the future and put into practice the most desirable models. Today it has become clear that the transition of the Biosphere to the Noosphere and the formation of the realm of the mind is a historical process in material and spiritual aspects. The emergence of the noosphere quality of the sociosphere will occur when the basic forms of collective and individual consciousness acquire the properties of anticipation of being. It is about the formation of noosphere intelligence as a certain collective mind of the whole civilization, uniting the intellects of individuals and the means of informatization and mediatization, including artificial intelligence and the Internet.

Among the educational structures of the new society, a special place will be occupied by basic education, the main purpose of which is to train the knowledge elite. Training, knowledge and information make a person competent in their own field of activity. Ukraine's entry into the noosphere process together with the world community requires future teachers of noosphere geography to master the system of noosphere competencies. Under these conditions, the priority of the future teacher is to master the ability to learn to receive new information – that is, to develop the ability to lifelong learning. Avsheniuk N. M. with co-authors (2014) note: A special actualization of the globalization of all spheres of life of the individual and society in the general civilizational tendencies of the modern world, which requires higher education to provide young people with basic opportunities to integrate into different

societies, self-determination, active, competitive in the world labor market.

The authors hope that the content of Noosphere geography, which will be the leading system of education, will be directed to fundamental education. Ursul A. D. (2009) also hopes for this, noting that it will be ahead of other spheres of social activity, as information processes will be ahead of material and energy ones. The process of futurization of education must be developed for the formation of a leading human consciousness, given both to anticipate the future and to put into practice the most desirable models.

With a well-thought-out and scientifically sound organization of the educational process, this will be realized in the development of the sphere of the mind. UNESCO experts believe that noosphere education is a long process that should take place at all educational levels and include many different educational projects in which the entire knowledge system is involved. In addition, says Lishchytovych L. I. (2019, pp. 211–212) UNESCO experts identify the following possible types of training:

• **transmissive learning,** learning includes the active provision of information from both the teacher and additional learning materials;

• **discovery learning,** learning includes elements of mystery and encourages curiosity and research (in Ukraine, educational research has been conducted since 1996 according to the manual of Chernov B. O. and Korneeva V. P.);

• **participatory / collaborative learning**, learning includes active joint solution of related tasks and problems;

• **problem-based learning,** learning requires students to solve educational problems of a global nature (in Ukraine published in 2007 a work on problem-based learning of geography at school Topuzov O. M.);

• **disciplinary learning,** teaching fixed in a certain field of knowledge (Chernov B. O. and Topuzo O. M. issued for secondary school each more than 10 textbooks in geography);

• **critical thinking-based learning,** which seeks to explore the views of stakeholders when they are in conflict;

• **systems thinking-based learning,** learning focused on relationships to explore and learn about system integrity.

Lishchytovych L. I. adds:

• **training to work with noosphere databases and knowledge,** where a person gets the opportunity to immediately find a scientifically sound solution based on a proven mathematical model;

• **the study of noosphere morality,** where man must undergo a reset of his individual, social and planetary consciousness;

• **training in the basics of noosphere justice,** which studies the procedure for standardizing the use of natural resources and the right of everyone to employment at any age and who will be interested in obtaining basic knowledge.

The authors are convinced that there are especially many opportunities for intelligent matter to capture and substantiate the patterns of development of Nature in relation to the development of society. This is possible in a complex science – Noospheric geography, which is based on the forms of matter motion of.

Based on the analysis of the general growth of intellectual technologies, Senchenko M., Senchenko O. and Hastynshchykov V. (2016) came to the conclusion that there is a feature in the Ukrainian mentality, which in some cases manifests itself as a «promoter of innovation». We do not have a firmly formalized view of the state of affairs. We see better the variability of spaces and structures, their inconsistency with formal patterns, and therefore, we catch the invisible possibilities that «have no name», i. e. innovation. This allows us to think about the Ukrainian project not just as a project to create an innovative economy, but rather as a formula for building a national innovation culture.

It was found that Ukraine with its high spirituality, science and culture can act as an organizer of the development of the idea of the noosphere and noosphere geography. The authors hope that research in this field will be continued by domestic geographers, as it is extremely important for geography and geographers themselves. M. V. Bagrov eloquently and convincingly noted this: «We are pleased to note that geography is not yet ready for such changes in its own vectors of development. In the information environment, she is still like Cinderella, but if we miss the chance to open up and declare ourselves, we can become the «Baba Yaga». Unfortunately, such an undesirable transformation is possible» (Bahrov M. V. 2008).

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Regional reclamation landscape technical systems: current status and rational use

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Abstract. The problems of the current state of possibilities of reconstruction and rational use of regional reclamation landscape technical systems have been considered. It has been noted that for studying the process of their formation and modern functioning GIS-method (GIS-packages SAS.Planet.Release and GoogleEarthPro) were used in addition to field landscape research. The meaning of the concept of "reclamation landscape technical system" as a structure in which interconnected hydraulic structures and water bodies that are necessary to ensure and maintain the optimal operation mode of the reclamation landscape complex has been clarified. The main types of reclamation such as hydraulic, cultural, chemical, agrotechnical and agroforestrytechnical have been partially discribed. The essence of the concept of "hydraulic reclamation" as a set of measures aimed at improving the water-air (waterlogging and dehydration) regime of soils has been considered more detailed. The expediency of resumption of reclamation measures in the territory of Ukraine has been confirmed, as 2/3 of its area is in conditions of unfavorable water regime. This study is focused on the analysis of drainage and humidification systems as the most effective in ensuring the regulation of excessive moisture or its deficit. It has been shown that the peak of reclamation works and construction of reclamation landscape technical systems was observed 1950–1965. The largest irrigation, drainage, polder and drainage-humidification systems in Ukraine have been discribed. It has been found that the decline of reclamation systems began in 1991 and was characterized by a reduction in the area of irrigated and drained lands and the deterioration of their ecological condition. Emphasis has been placed on the study of regional drainage and humidification systems and three stages of their development in Ukraine have been identified. Possible measures for the rational use of reclamation systems on the example of the Trubizh regional drainage and humidification landscape technical system have been proposed. It has been noted that the development of regional plans for the rational use of this system should be based on the analysis of the history of economic development of the Trubizh river basin and taking into account the specifics of the landscape structure of the canal-floodplain type. Reconstruction of the reclamation system has been recommended to conduct in two stages: the first one is based on the modernization of hydraulic structures and the main canal, the second one is based on the internal and landscape structure of the system. The feasibility of partial restructuring of the open network for closed drainage and the creation of temporary drainage channels has been confirmed, which will allow more rational use of resources of the Trubizh reclamation landscape technical system.

Ключові слова: region, reclamation landscape-technical systems, hydraulic reclamation, Trubizh drainage and humidification system, measures, rational use.

Регіональні меліоративні ландшафтно-технічні системи: сучасний стан, раціональне використання

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Анотація. Розглянуто проблеми сучасного стану можливостей реконструкції та раціонального використання регіональних меліоративних ландшафтно-технічних систем; зазначено, що пізнання процесу їх формування і сучасного функціонування, крім польових ландшафтознавчих досліджень, було здійснено за допомогою ГІС-методу (ГІС-пакети SAS.Planet.Release і GoogleEarthPro). Уточнено зміст поняття "меліоративна ландшафтно-технічна система", як структури у якій функціонують взаємопов'язані гідротехнічні споруди і водні об'єкти, необхідні для забезпечення та підтримання оптимального режиму функціонування меліоративного ландшафтного комплексу. Частково схарактеризовано основні види меліорації – гідротехнічну, культуртехнічну, хімічну, агротехнічну й агролісотехнічну; детальніше розглянуто сутність поняття "гідротехнічна меліорація", як комплексу заходів спрямованих на поліпшення водно-повітряного (перезволоження і переосушення) режиму ґрунтів. Підтверджена доцільність відновлення проведення меліоративних заходів на території України, оскільки 2/3 її площі знаходиться в умовах несприятливого водного режиму. Зосереджено увагу на аналізі осушувально-зволожувальних систем, як найбільш ефективних при забезпеченні регулювання надмірної вологи або її дефіциту. Показано, що пік проведення меліоративних робіт і спорудження меліоративних ландшафтно-технічних систем припадає на 1950–1965 рр. Наведені найбільші в Україні зрошувальні, осушувальні, польдерні й осушувально-зволожувальні системи. Виявлено, що занепад

меліоративних систем розпочався у 1991 р. і характеризувався скороченням площ зрошувальних і осушувальних земель та погіршенням їх екологічного стану. Акцентовано увагу на дослідження регіональних осушувально-зволожувальних систем і виділено три етапи їх розвитку на території України. Запропоновано можливі заходи з раціонального використання меліоративних систем на прикладі Трубізької регіональної осушувально-зволожувальної ландшафтно-технічної системи. Зазначено, що розробку регіональних планів щодо раціонального використання цієї системи необхідно здійснювати на основі аналізу історії господарського освоєння басейну річки Трубіж та врахування специфіки ландшафтної структури канально-заплавного типу місцевості. Рекомендовано проведення реконструкції меліоративної системи у два етапи: перший ґрунтується на модернізації гідротехнічних споруд і магістрального каналу, другий – внутрішньогосподарської і ландшафтної структури системи; підтверджено доцільність часткової перебудови відкритої мережі на закритий дренаж та створення тимчасових осушувальних каналів, що дасть можливість раціональніше використовувати ресурси Трубізької меліоративної ландшафтно-технічної системи.

Ключові слова: регіон, меліоративні ландшафтно-технічні системи, гідротехнічна меліорація, Трубізька осушувально-зволожувальна ландшафтно-технічна система, заходи, раціональне використання.

Introduction.

One of the main conditions for the development of Ukraine's economy is to increase the profitability and competitiveness of agricultural production, providing the population with food, and industry with raw materials and the creation of highly developed agro-industrial complexes. At present, it is impossible to grow crops without reclamation measures, as a significant part of the territory of Ukraine (75 %) is in the zone of insufficient moisture supply, another 15 % – in the zone of excessive moisture. The efficiency of reclamation measures depends on the technical condition of the existing irrigation and drainage networks. However, the reduction of investment significantly reduces the efficiency of reclamation systems, which leads to their deterioration. Most hydraulic structures have exhausted their resources and are in poor condition. Currently, the area of irrigated land is 600 thousand hectares out of the available almost 2.2 million hectares. Drainage systems are characterized by siltation of drainage canals, which results in flooding of areas overgrown with weeds and shrubs. All these require solving a number of problems, including development of effective measures to optimize the reclamation network and reconstruction of hydraulic structures; ecological substantiation of modern reclamation measures; the problem of reclamation at the regional level is insufficiently studied. Solving these problems will make it possible to intensify agricultural production and improve the environmental situation on reclaimed lands.

Analyzing the works of domestic and foreign scientists, it has been noted that most of them are devoted to the general development of land reclamation and water management in the leading countries of the world or in Ukraine. They investigated the current state of water reclamation systems and the possibility of their reconstruction in order to make functional improvements (Shi et al., 2018); thermodynamic balancing of heat and mass transfer processes in drainage and humidification systems (Elzayeda et al., 2020); integration of reclamation works into balanced land management (Leucuta et al., 2016); restrictions and trade-offs related to the reclamation of abandoned sown areas in order to assess potential crops in Ukraine and Kazakhstan (Meyfroidt et al., 2016); the causes of the decline of most reclamation systems and suggested ways to update and improve their condition (Krolikowska et al., 2009); ways to optimize the design of horizontal drainage in reclaimed clay-sandy layered soils (Feng et al., 2020); ways to optimize reclamation systems of water circulation type in order to reduce the negative impact of wastewater on the environment (Rezaei et al., 2019); prospects for land reclamation development in Ukraine (Baliuk, 2018); current state of irrigation and drainage in Ukraine, ways of reconstruction and restoration (Dekhtiar, 2019); land reclamation and optimization of soil processes (Lozovitstyi, 2014); development of land reclamation and water management of Ukraine according to world trends (Kovalenko, 2009); problems of reforming the agricultural sector of the economy and unbundling of reclaimed lands, which led to a violation of the integrity of reclamation systems (Dmytrenko, 2011); drainage and irrigation systems on the territory of Ukraine and stages of their creation (Kyryliuk & Lebedovskyi, 2020). However, only a few scientists focus on studying the problems of development of regional reclamation systems, in particular irrigation (Yatsenko, 2014).

The purpose of the work is to analyze the current state of reclamation systems in the territory of Ukraine on the example of the Trubizh regional drainage and humidification landscape-technical system and to propose measures for their rational use.

Materials and methods of research.

In the process of analyzing the current state of regional reclamation systems, the following methods were used: system analysis (made it possible to analyze the work of structural elements of the system and the relationship between them); statistical (revealed a tendency to reduce the area of irrigated and drained land relative to the area of water-scarce and humid territory); generalization (made it possible on the basis of the obtained data on structural elements to draw a conclusion about the system as a whole); historical and landscape science (used to identify the degree of anthropogenic changes in the development

of the Trubizh drainage and humidification system); airbrushing (used to identify and analyze hydraulic structures on the main canal); final results (allows to analyze the features of the construction process and the modern landscape structure of the Trubizh reclamation system); GIS method (used in the analysis of changes in natural landscape complexes and their transformation into anthropogenic ones).

The data presented in this article have been obtained using the method of analysing archival, statistical and cartographic materials, as well as from our own field and analytical research. SIS.Planet.Release and GoogleEarthPro GIS packages have been used to analyze modern landscape complexes of the Trubizh drainage and humidification system.

Results and their analysis.

The analysis of the current state of regional reclamation systems should begin with an understanding of the concept of "reclamation system". In the Geographical Encyclopedia of Ukraine the concept of "reclamation system" is interpreted as "a set of functionally interconnected hydraulic structures, machines and mechanisms, reservoirs, plantations, communication lines and power lines, roads, administrative and other structures necessary to ensure and maintain optimal water, air and thermal regimes of soils" (Mykhailov, 1990).

According to the Draft Law of Ukraine "On Amendments to Certain Legislative Acts of Ukraine on the Use of Reclaimed Land and Reclamation Systems", reclamation system is a "technologically integrated engineering system consisting of one or more reclamation networks and designed to provide an ptimal water, heat, air and nutrient regime of soils on reclaimed lands" (Proekt Zakonu Ukrainy, 2016). Here are the main types of reclamation depending on the direction of the carried-out actions specified: hydraulic, cultural, chemical, agrotechnical and agroforestrytechnical. We will dwell in more detail on the consideration of hydraulic reclamation, as it has the greatest impact on improving natural conditions and changing the water-air regime of the soil of the territory.

Hydrotechnical reclamation should be understood as a set of measures aimed at improving the water and air regimes of soils (over-drained and wet) and protecting them from flooding and erosion. Hydraulic reclamation involves the creation of main and distribution channels, water mains, pumping stations, reservoirs, dams, collector and drainage network and other hydraulic facilities. The following measures are taken during hydraulic reclamation as drainage, irrigation, drainage and humidification, flood protection, anti-erosion and anti-mudflow.

Since 2/3 of the territory of Ukraine is in condition of unfavorable water regime, the implementation of effective reclamation measures has a certain zonal feature. According to hydrological zoning, the plain territory of Ukraine is within three zones: excessive water content (Polissia and Desna regions of excessive water content); sufficient water content (Western and Left Bank-Dnipro regions of sufficient water content); insufficient water content (Lower Buh-Dnipro, Severskodonetsk-Dnipro, Black Sea and Azov regions of insufficient water). Therefore, in order rationally to use the land and get high yields of crops, it is necessary to apply drainage reclamation, and in arid – irrigation in wetlands.

The introduction of reclamation measures on the territory of Ukraine began in the second half of the 19th century with an expedition led by General I. Zhilinsky. These were primitive drainage systems with open canals, which later became swampy due to flooding during the floods. Irrigation of lands began at the beginning of the 20th century. The first irrigation system was built in 1915 in the village of Vyscha Tarasivka, Ekaterinoslav Province (Kyryliuk & Lebedovskyi, 2020). Irrigation took place by surface irrigation with self-flowing and rarely mechanical water supply. In 1917, the area of irrigated land was 17 thousand hectares, and drainage was 430 thousand hectares (Mysyk & Kulikovskyi, 2005).

Active construction of reclamation systems occurred in 1950–1965, which resulted in an increase in the area of irrigated and drained lands (in 1965– 543 thousand hectares and 1373 thousand hectares, respectively). The largest irrigation systems on the territory of Ukraine are Kakhovsk (262 thousand hectares), Pivnichno-Rohachytska (81.8 thousand hectares), Krasnoznamiansk (72.5 thousand hectares), Ingulets (62.7 thousand hectares), Yavkynsk (50 thousand hectares), Sirohozk (41.6 thousand hectares), Nyzhnodnistrovsk (37 thousand hectares), Frunze (35.3 thousand hectares), Pryazovsk (31.8 thousand hectares), Tatarbunary (31.7 thousand hectares), Dunai-Dnistrovsk (29.2 thousand hectares) and water bed. Subsequently (after 1961) these reclamation systems began to be built using anti-filtration lining of channels with monolithic concrete (Lozovitstyi, 2014). In the same years they began to build drainage and drainage-wetting systems with open channels and wetting sluices on them and mole drainage actively, which allowed bilateral regulation of the water-air regime of soils.

The construction of polder drainage systems with machine drainage has begun in 1985. According to the data given in the "Resolution on the comprehensive program for the development of land reclamation and improvement of the ecological condition of irrigated and drained lands in the territory of Ukraine", the area

of polder systems is 317 thousand hectares (Postanova, 2000). In the Geographical Encyclopedia of Ukraine, the concept of "polder systems" is interpreted as "a type of drainage systems, water regulation of which is based on the protection of dams reclaimed areas (polders) from flooding rivers, reservoirs, lakes or seas" (Grynevetskyi & Korotun, 1990). The largest polder systems in the territory of Ukraine are Trubizh drainage and humidification system (37.6 thousand hectares); Verkhnoprypiat drainage and humidification system (25.1 thousand hectares); Berehivska drainage and humidification system (23 thousand hectares) and Irpin drainage and humidification system (8.2 thousand hectares).

Since 1991, reclamation activities have been partially suspended, which has affected the efficiency of reclamation systems. Large main canals remained working on irrigated lands, while the rest were almost unused or destroyed. The same tendencies are observed in the work of drainage systems, which, as a result of the cessation of supervision, almost all became silted up and overgrown with wetland vegetation.

According to the Strategic Environmental Assessment Report, in recent years the area with insufficient moisture supply has increased by 7 % (compared to 1990), which amounts 11.6 million hectares (37 %) of arable land in Ukraine, and the area with excessive and sufficient moisture has decreased by 10 % (compared to 1990) and occupies 7.6 million hectares (22.5 %) of arable land. However, according to official statistics for 2017, specified in the Strategy of Irrigation and Drainage in Ukraine, the area of irrigated land is 2178.3 thousand hectares (19 % of the total area of water-scarce land), and drainage is 3307.0 thousand hectares (43.4 % of the total area of the humid territory). It is also noted that as of 2017, irrigation was carried out on an area of less than 500 thousand hectares (less than 23 % of the total irrigation area), and drainage was on an area of more than 250 thousand hectares (7.5 % of the total drainage area) (Upravlinnia zemelnykh ta vodnykh resursiv, 2019).

The beginning of the 21st century characterized by a significant reduction in the area of reclaimed land and the deterioration of their ecological condition. As a result of irrational reclamation measures, irrigated lands are characterized by significant flooding (15–20 %), salinization (6–9 %) and secondary salinization (30–40 %), and drainage lands are characterized by rapid operation of the peat layer, which led to the emergence of sands in some cases (Kanash, 2005). The area of lands on which it is necessary to carry out complex reconstruction of irrigation and drainage systems makes 491.5 thousand hectares (22.5 % of all irrigated lands) and 175.4 thousand hectares (5.3 % of the total area of drainage), accordingly (Puhachov, 2003).

Among hydraulic reclamation systems it is necessary to single out systems of bilateral action (drainage and humidification) which are the most effective and provide regulation of excess moisture or its deficiency by means of artificial drainage in combination with periodic irrigation of the lands. In the glossary-reference book on construction and architecture, the concept of "drainage and humidification system" is considered as "a complex of hydro-ameliorative structures of bilateral action to regulate the water-air regime of the soil on drained lands; reclamation system that combines the functions of drainage and irrigation systems" (Shmyh, 2010).

According to the "Resolution on a comprehensive program for the development of land reclamation and improvement of the ecological condition of irrigated and drained lands in the territory of Ukraine", bilateral regulation of the water regime is carried out on an area of 1.1 million hectares (Postanova, 2000). The largest hydraulic reclamation systems of bilateral action of Ukraine are Trubizh drainage and humidification system (37.6 thousand hectares); Oster drainage and humidification system (34.2 thousand hectares); Upper Pripyat drainage and humidification system (25.1 thousand hectares); Berehivska drainage and humidification system (23 thousand hectares); Zamyslovets drainage and humidification system (16 thousand hectares); Romensk drainage and humidification system (14.9 thousand hectares); Irpin drainage and humidification system (8.2 thousand hectares) and Kyshynska drainage and humidification system (3.5 thousand hectares) (Dupliak, 1989, 1990, 1993).

According to the territorial principle, reclamation landscape-technical systems are divided into regional, subregional and local (Grodzynskyi & Shyshchenko, 1993). We will focus on regional reclamation systems, as they are the subject of our study. By regional reclamation landscape-technical systems we mean reclamation systems covering the territories of physical-geographical regions (Chernihiv Polissya and Pivnichnoprydniprovsk terrace lowland) or several administrative districts. In the development of regional drainage and humidification systems of Ukraine it is expedient to distinguish three periods: 1st period (1954–1966) – construction of reclamation systems based on the introduction of industrial technologies; 2nd period (1970–80's) – reconstruction and technical re-equipment of reclamation systems, which provides for partial reconstruction of the open network for closed drainage; 3rd period (beginning of the 21st century) is characterized by a significant decline of reclamation systems, siltation and overgrowing of the drainage network. Modern regional drainage and humidification landscape technical systems are characterized by the use

of traditional hydraulic structures that have operational shortcomings, resulting in reduced efficiency of drainage lands, in particular the uneven regulation of water and air regime of soils.

An example of a regional polder landscape technical system is one of the first and largest in Ukraine Trubizh drainage and humidification system of bilateral action, covering parts of Kyiv and Chernihiv regions. It was built in 1954–1962 in order to increase the area of land for growing vegetables and fodder crops in accordance with the "Great Plan for the Transformation of Nature". The river Trubizh was transformed into a main canal, the length of which is 124.6 km (it should be noted that the length of the river is 113 km), and forms a parabola in cross section with parameters P = 6–18 m, where the upper width of the canal varies from 9.2 to 29 m, and depth – 2.6–3.8 m (Zapolskyi, 1991). According to the Geographical Encyclopedia of Ukraine, the area of reclaimed lands is 37.6 thousand hectares (Dupliak, 1993).

The Trubizh reclamation landscape technical system consists of the following parts: regulating, fencing and exhaust. 1125 hydraulic structures were built on this system, including 827 sluice-regulators, 18 bridges and 128 crossings. 19 sluices for water supply to the lateral control network and 12 bridges have been built on the main canal. The design of Trubizh reclamation system belongs to the mixed type. Drainage and humidification occur due to open canals (total length 1238 km) and closed drainage (12.5 thousand hectares) (Dupliak, 1993). In 1983, the system was reconstructed, which provided for the reconstruction of the open network for closed drainage with an area of 25 thousand hectares.

As a result of the construction of the Kaniv Reservoir, the method of draining excess water from the drainage area has changed. The result is the restructuring of the Trubizh self-flowing system into a machine (polder), where the drainage of water from the drainage network is carried out by means of a pumping station. This method of drainage is used when the water level in the water intake is higher than the water level in the main channel. Thus, the water level difference between the Kaniv Reservoir and the Trubizh River is 6 m. The third part falls on reclaimed lands. The massif consists of the following main structures: three water-enclosing dams with a total length of 12.5 km, with a mark of ridges – 93–94 m and a width along the ridge – 5.5–8 m; drainage channel 6.7 m long; pumping station with a design capacity of 85 m^3/s (EUWI +, 2019).

As a result of irrational reclamation works, Trubizh was shallowed (especially during dry periods). In order to reduce the water deficit of the river, the Desna-Oster-Trubizh aqueduct was built. Water is supplied by 4 pumping stations along the regulated Ostra river, which is connected to the upper reaches of the Trubizh by a derivation channel. The design capacity of these stations is 3 m^3/s. With the help of such a technical solution, the moistening of productive lands (30 thousand hectares) has the maximal economic effect. Thus, the pumping of water through the derivation channel is carried out by pumping stations No.1 and 4, and stations No 2 and 3 operate on the principle of cascade lifting and pumping water from the lower to the upper reaches of the sluice.

Due to the lack of proper supervision of the reclamation network and hydraulic structures, the territory is re-wetted, and the irrational use of reclaimed lands has led to soil depletion and changes in vegetation (spread of shrubs). Therefore, the rational use of the Trubizh regional drainage and humidification landscape technical system should be based on the reconstruction of the system itself and the implementation of reclamation measures, taking into account the specifics of landscape complexes that are reclaimed.

Rational use of the studied system should be carried out on the basis of the structural-dynamic model proposed by V. B. Mikhno. This model consists of three interconnected blocks: 1) the interaction of man and landscapes that reflects the peculiarities of the interaction of man and aquatic landscape complexes; 2) information that is the collection of data that reveal the features of the system, the specifics and ecological status of landscape complexes and ways of rational use; 3) implementation that is modeling and design of the studied landscapes (Mikhno, 2000).

In order to use rationally the Trubizh regional drainage and humidification landscape technical system, it is necessary to determine and analyze the specifics of nature, the current state of landscape complexes, the level of anthropogenic load and the interaction of the reclamation system with adjacent landscapes. Therefore, taking into account the above factors, we propose the following measures for the rational use of reclamation systems:

– activization of scientific research in order to improve the management technologies of regional drainage and humidification systems;

– development of regional plans and projects for the restoration of the Trubizh reclamation system, which will be based on the history of river development and the specifics of the canal-flood type of the area. A significant part of the reclamation network has lost its effectiveness due to siltation and overgrowing of wetland vegetation, resulting in an increase in the area of wetlands and reduced land fertility;

– involvement in the development of projects for the rational use of the reclamation system not only specialists in the field of water management and reclamation, but also hydrologists, geographers, ecologists, biologists, spacialists in nature protection and engineers. Whereas such integration of the various

branches of science will make it possible to predict both the negative and positive consequences of the functioning of this system and to develop measures for its rational use;

– carrying out the measures on of drainage systems that are in unsatisfactory condition. Modernization should be carried out on the basis of the use of sluice technology, which will expand the functionality of drainage systems, namely: regulation of the water regime throughout the growing season of crops. Modernization of non-functioning drainage systems should be based on repair and restoration works: clearing of canals, reconstruction of water-regulating constructions, washing and partial restoration of drainage;

– reconstruction of the open control network partially into the closed drainage. Open network is simpler and cheaper to build, but requires high operating costs and often takes up space that can be used for agricultural production. Closed drainage is more expensive in terms of construction, but reduces operating costs and occupies a small usable area of land;

– reconstruction of the reclamation system in two stages. The first stage is the repair and increase of the capacity of the main and inter-farm canals and the reconstruction of hydraulic structures. The second stage is the reconstruction of the internal economic system;

– construction of temporary drainage canals (if necessary) for the purpose of rational use of the area for agricultural lands. These canals are built for a short period (usually for one season), annually cut and leveled, which makes it possible to regulate the drainage of the territory depending on the weather;

– to recommend to the Trubizh interdistrict management of water management to carry out inventory of green plantings in coastal protective strips for identification of the dry trees which complicate water capacity;

– clearing of the main canal from siltation in order to create rheophilic conditions (current) and avoid further waterlogging.

Conclusion.

Carrying out reclamation measures on the territory of Ukraine is a necessary condition of the development of agricultural production. Currently, almost 90 % of the country area is within the arid (water-deficient) and humid (excessively moist) zones, which leads to the implementation of such hydraulic measures as irrigation and drainage, respectively. The creation of the first reclamation systems began at the end of 19th century, but the peak of reclamation works and industrialization of these systems occurs in the 50–60's of the twentieth century. The effectiveness of reclamation measures should be based on creating the conditions for environmentally safe use of agricultural land and ensuring optimal water and air regime of soils. Nowadays, the need to ensure the integrated and rational use of reclamation systems is urgent. It is scientifically substantiated that dehumidification and humidification systems are the most effective and provide regulation of excess moisture or its deficit. However, these systems have many unconsidered aspects and imperfections in their construction, the analysis of which allows to develop measures for rational use. An example of such a system is one of the most powerful in Ukraine Trubizh polder regional drainage and humidification landscape technical system. Measures for the rational use of this reclamation system should be carried out taking into account the peculiarities of the state and development of modern landscape complexes and the level of anthropogenic pressure on them. Among such measures it is necessary to allocate development of the scheme of restoration of the investigated system; reconstruction of hydraulic structures and partial reconstruction of the open reclamation network into a closed drainage; creation of temporary drainage canals that will allow the rational use of space for agricultural land; and implementation of adjustment of reclamation impact on the landscape complexes of Trubizh due to the peculiarities of soil structure and groundwater level.

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Transport infrastructure of Spain as a factor in tourism development.

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Abstract. This article considers features of functioning of a modern transport network. Transport is an important area of infrastructure supply for the population and the state economy, the key function of which is the movement of people and goods. The current transport complex is subject to contradictory trends: as an infrastructure industry, transport is located in a position dependent on the production of social goods, and as a special sector of the economy, transport has an important impact on the regional location of production capacity and participates in the process of reproduction part of the system of economic relations. The importance of transport infrastructure in the economy, its development and operating conditions are difficult to overestimate. After all, it is the basis of the supporting framework of territorial social systems of any level. On the current state, level and opportunities for the development of the transport infrastructure depends not only the social and economic growth of territorial economic systems, but also their spatial development. Tourism plays a significant role in the development of transport infrastructure. Europe is one of the most attractive regions for tourists in the world. In turn, Spain is one of the most popular destinations for tourists from around the world as well as for European tourists. Spain plays an important role in tourist traffic in Europe. This is facilitated by its efficient transport and geographical location, developed production infrastructure, as well as historical aspects. Spain is a key country of transit by air and sea with the Americas. The flat terrain promotes the development of road and rail passenger transport across the centre of the country. And given the attractiveness to tourists and direction of tourist flows to the regions of the country, the study of geographical features of transport infrastructure is quite relevant. The peculiarities of the functioning and formation of the transport infrastructure of Spain are considered. The geographical features of the development of the infrastructure of railway, road and sea and air transport of Spain are analyzed. As for the terminals in the regions of Spain, their number also corresponds to the number of airports. Therefore, the largest number of terminals is in the Canary Islands – 9 (all airports have one terminal, except Lanzarote). There are 8 terminals in the airports of Andalusia, where all airports except Malaga have one terminal, in Malaga there are three. The two Madrid airports have 6 terminals, but 5 of them are located at the country's main airport – Madrid-Barajas. Catalonia's airports have 5 terminals, two of which are located in Barcelona El Prat. There are 4 terminals in Galicia – one each in Vigo and La Coruna and two in Santiago de Compostela. There are 4 terminals in Galicia – one each in Vigo and La Coruna and two in Santiago de Compostela. In all other regions, the number of terminals is proportional to the number of airports. An assessment of the level of development of transport infrastructure for tourism in the regions of Spain was conducted. On the basis of quantitative indicators of the analysis of the transport infrastructure of Spain, a point assessment of the level of development of the transport infrastructure of the country's regions for the needs of tourism was carried out. Administrative units are divided into 5 groups: with the highest, high, sufficient, medium and low level of development of transport infrastructure for tourism. Transport infrastructure is most developed in the tourist regions of the country – Catalonia, Andalusia, Madrid, the Canary and Balearic Islands.

Ключові слова: transport infrastructure in tourism, transport complex, transportation, highways, railways, air transport, airports, passenger turnover.

Транспортна інфраструктура Іспанії як чинник розвитку туризму.

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Анотація. Встановлено значення транспортної інфраструктури в господарстві, її розвиток та умови функціонування важко переоцінити. Адже саме вона є основою опорного каркасу територіальних суспільних систем будь-якого рівня. Від сучасного стану, рівня та можливостей розвитку транспортної інфраструктури залежить не тільки соціальне та економічне

зростання територіальних господарських систем, але й їх просторовий розвиток. Значний поштовх для розвитку транспортної інфраструктури відіграє туризм. Європа є одним із найбільш привабливих для туристів регіонів світу. В свою чергу Іспанія є одним з найбільш популярних напрямків як для туристів зі всього світу, так і для європейських туристів. Іспанія відіграє велике значення в туристичних перевезеннях в Європі. Цьому сприяє ефективне транспортно-географічне положення, розвинена виробнича інфраструктура, а також історичні аспекти. Іспанія є ключовою країною в транзитному авіаційному та морському сполученні з країнами Америки. Рівнинний рельєф сприяє розвитку автомобільних та залізничних пасажирських перевезень в середині країни. А враховуючи туристичну привабливість та напрямки туристичних потоків до регіонів країни, дослідження географічних особливостей розвитку транспортної інфраструктури є досить актуальним. Розглянуто особливості функціонування та становлення транспортної інфраструктури Іспанії. Проаналізовано географічні особливості розвитку інфраструктури залізничного, автомобільного, морського та авіаційного транспорту Іспанії. Здійснена оцінка рівня розвитку транспортної інфраструктури для потреб туризму за регіонами Іспанії. На основі кількісних показників аналізу транспортної інфраструктури Іспанії проведено бальну оцінку рівня розвитку транспортної інфраструктури регіонів Іспанії для потреб туризму. Адміністративні одиниці поділено на 5 груп: з найвищим, високим, достатнім, середнім та низьким рівнем розвитку транспортної інфраструктури для потреб туризму. Транспортна інфраструктура найбільше розвинена в туристичних регіонах країни – Каталонія, Андалусія, Мадрид, Канарські та Балеарські острови.

Ключові слова: транспортна інфраструктура в туризмі, транспортний комплекс, перевезення, автомобільні дороги, залізничні колії, авіаційний транспорт, аеропорти, пасажирообіг.

Introduction.

The tourism industry cannot exist without proper transport provision and a developed tourism transport infrastructure. Vacationers who visit any region of the world for tourism or treatment and recreation purposes should receive quality transport services and be able to get to all recreational and tourist facilities, regardless of location.

The importance of transport infrastructure in the economy, its development and operating conditions, is difficult to overestimate. After all, it is the basis of the supporting framework of territorial social systems of any level. On the current state, level and opportunities for the development of transport infrastructure depends not only the social and economic growth of territorial economic systems, but also their spatial development. Tourism plays a significant role in the development of transport infrastructure.

Europe is one of the most attractive regions for tourists in the world. In turn, Spain is one of the most popular destinations for tourists from around the world, including for European tourists. This country plays an important role in tourist traffic in Europe. This is facilitated by the efficient transport and geographical location, developed production infrastructure, as well as historical aspects.

Spain is a key country in transit by air and sea with the Americas. The flat terrain promotes the development of road and rail passenger transport across the centre of the country. And given the attractiveness to tourism and direction of tourist flows to the regions of the country, the study of geographical features of transport infrastructure is quite relevant. Existing geographical studies of transport infrastructure are not in-depth, especially at the regional level; this analysis allows us to argue for the feasibility of studying the transport infrastructure of Spain as a basis for the development of tourist infrastructure.

Research methods.

The study uses literary, analytical, comparative, mathematical and statistical methods and the method of scientific systematization.

The purpose of the work is to characterize the transport infrastructure of Spain as one of the main factors for the development of tourist infrastructure.

Results and their analysis.

It is known that the tourism industry, given its significant impact on the economic and social development of the country, the branching of economic ties, needs regulation, support and careful control by the state (Boyko, Horozhankina, Hrushka, Korneyev, Nebaba, 2020). The main body that regulates all transport relations in the country is the Ministry of Development of Spain (Ministerio de Fomento de España, 2020). It is a governing body responsible for the preparation and implementation of state policy on land transport infrastructure, air and maritime jurisdiction of the state, control and management and regulation of transport services of administrative services, management and direction of all postal and telegraph services, development and direction of public services, which are related to astronomy, geodesy, geophysics and mapping, investment planning and programming, which are related to the above services. The structure of the Ministry of Development includes the State Secretariat for Infrastructure, Transport and Housing and Communal Services, which in turn has the General Secretariat for Transport. It has separate units that are responsible for a particular mode of transport: the General Directorate of Civil Aviation, the General Directorate of the Merchant Navy, the General Directorate of Land Transport. The powers of the General Directorate of Land Transport include the regulation of relations in road, rail and pipeline transport. In addition to the Ministry of Development, each mode of transport has public and private companies that control the organization of transportation (Renfe Operadora, 2020).

Tourism in Spain has become a sphere of implementation of market mechanisms, a source of replenishment of state and local budgets, the distribution of financial flows (Podlepina, 2013).

The seaports of Spain are subordinated to the public organization Public Ports (Puertos del Estado, 2020). The company implements the government's port policy, coordinates and monitors the efficiency of the port system, which consists of 28 port authorities that manage 46 ports of general interest (International Air Transport Association, 2020).

In the field of rail transport there is an operator Renfe (Renfe Operadora, 2020), which is the state railway network of Spain. The length of the network is 15,000 km. Most of the railway lines have a wide gauge (1668 mm), which is wider than the Ukrainian (1520 mm) and European (1435 mm) track width. Part of the network, the AVE high-speed rail, which has a standard European track width. The company was founded on January 24, 1941 at the same time as the nationalization of the Spanish railways. To create a competitive transportation market, on January 1, 2005, RENFE was divided into an infrastructure management agency (stations, tracks, signaling, etc.) (ADIF) and the operating company RENFE (Renfe Operadora), which provides freight and passenger transportation (Chaika, 2016).

Infrastructure and road transport are controlled by SEITT – the State Land Transport Infrastructure Company. It aims to build and control the operation of roads (Puertos del Estado, 2020).

Spanish public airports are subordinated to the public organization Spanish Airports and Aeronautics (Aeropuertos Españoles y Navegación Aérea (Aena)). Aena is a Spanish state-owned company that operates public airports in Spain. The company operates 46 airports and 2 helicopter ports in Spain and participates through its subsidiary Aena Internacional, managing 15 airports in Europe and America. This makes it one of the leaders in terms of passenger volume in the world. Aena operates all airports of interest to public aviation in Spain, as well as air navigation at some private and some air bases in a mixed regime with the Spanish Armed Forces (Aeropuertos Españoles y Navegación, 2020).

Aena's subsidiary is ENAIRE, which is an air navigation manager in Spain and the Western Sahara, certified to provide control of routes, approaches and airport services. It is responsible for controlling air traffic, aeronautical information and communication networks, navigation and surveillance necessary for airlines and their aircraft to fly safely, smoothly and in an organized manner for Spanish airspace (ENAIRE, 2020).

The first railways in Spain were built in 1848 and have been developing rapidly since then. The total length of railways is 15,931.08 km as of 2019 (Fig. 1).

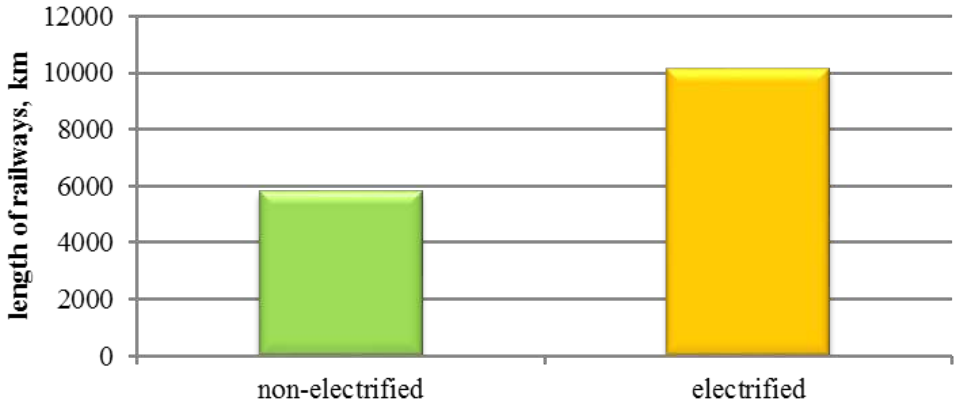


Fig. 1. Railways of Spain in 2019 (Renfe Operadora, 2020)

The length of electrified railways is more than 10,000 km, ie twice as long as non-electrified ones. The largest length of railways is in the largest regions of Spain – Castile and Leon, Andalusia, Castilla-La Mancha (more than 2000 km each) and in each of these regions the length of electrified railways is greater. These regions in terms of length of railways are followed by the autonomous regions of Catalonia, Aragon and Galicia. The share of electrified railways is particularly high in Catalonia, where the railroad runs along the Mediterranean resorts of the Costa Brava (International Civil Aviation Organization, 2020).

The length of the railways in Valencia is more is than 900 km, where the railways also run along the tourist resorts of the Costa Blanco. In Extremadura, Madrid and Asturias, the length of the railway is about 600–700 km. Extremadura has no electrified railways at all, and is one of the least economically developed and most sparsely populated areas of Spain.

And for Madrid and Asturias, given their area, this length of railways is quite great. In Madrid, most of the

country's railways intersect, given the city's functions, and in Asturias the railroad runs along the Atlantic coast. About 90 % of Madrid's railways are electrified. The situation is somewhat similar with Asturias in the Basque Country. The length of the railway is slightly shorter (560 km), but it also runs along the coast and major cities of the region and almost the entire railway is electrified. The smallest lengths of railways are typical for the smallest regions – La Rioja and the Balearic Islands (about 110 km each). In the Balearics, there is a railway only on the largest island of Mallorca and it performs tourist functions. There are no railways in the Canary Islands at all, nor in Ceuta with Melilla.

Spain currently has more than 1,500 km of high-speed rail lines connecting Madrid with Malaga, Seville, Valencia, Barcelona, Valladolid, Tarragona, Zaragoza, Alicante and Ferroli. In 2013, a high-speed line was built connecting Spain with France. Night trains run from Spain to Paris, Lisbon, Geneva, Zurich, Milan. If the program for the development of Spanish high-speed rail lines is implemented, by 2022 Spain will have 7,000 km of high-speed rail lines (according to national practice, these include lines with a speed of 200–250 km / h), which allow you to get from the provinces to Madrid in less than 3 hours and to Barcelona in 4 hours.

The distance of 630 km from Madrid to Barcelona is covered by a high-speed train in 2 hours and 38 minutes; taking into account the tourist passenger flow, this is the busiest route in Spain. Most of the railway network is owned by the state-owned company Adif, and rail traffic is regulated by the state institution RENFE. Regional companies (FEVE, FGC, Euskotren, FGV, SFM) also participate in this market (Renfe Operadora, 2020).

It should be noted that passenger traffic accounts for only 6.5 % of traffic, which is a rather low figure. In 2019, 576.1 million passenger journeys were made by Spanish railways. The distribution of passengers during the year is uneven (Fig. 2).

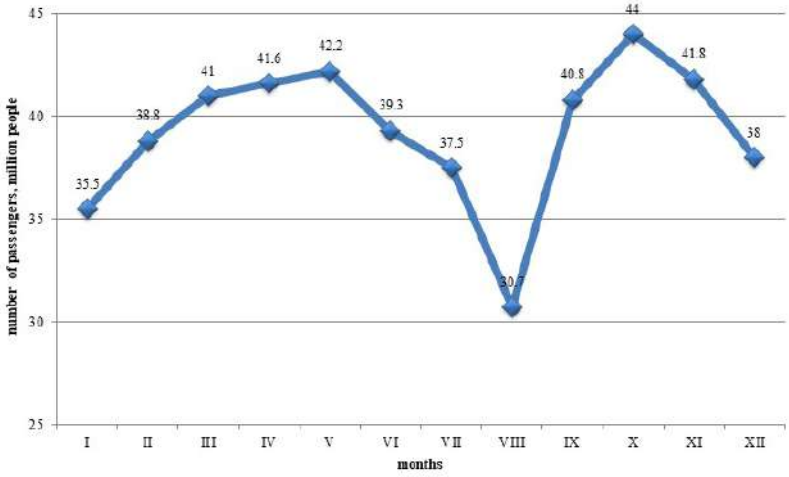


Fig. 2. Monthly dynamics of passenger traffic on Spanish rail transport in 2019 (Renfe Operadora, 2020)

Spain is the fourth largest country in Europe (after Russia, Ukraine and France) and has a fairly flat terrain. Due to this it has a fairly extensive network of roads and high rates of passenger transport by road. As of 2019, the total length of roads in Spain was 165,484 km, ie the density of the road network is 0.33 km / km2. Most roads are under the jurisdiction of the autonomous regions (43 %), slightly fewer are in municipal ownership (41 %) and another 16 % of roads are state-owned (Fig. 3).

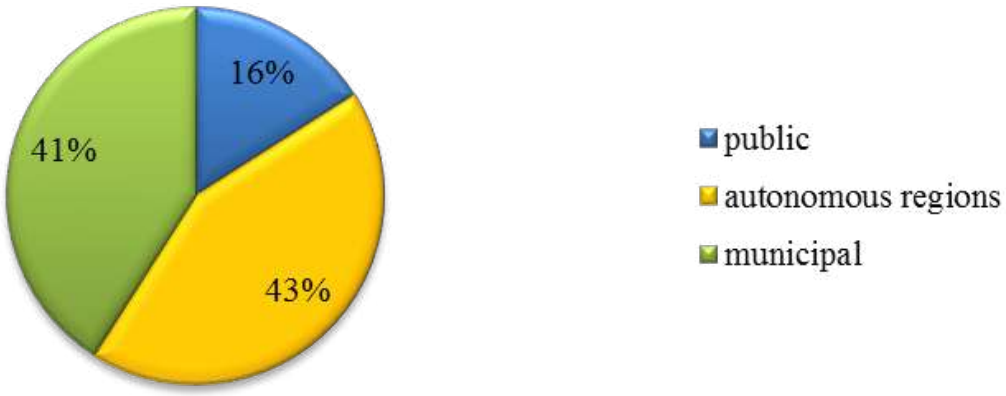


Fig. 3. Subordination of roads in Spain in 2019 (Renfe Operadora, 2020)

There is an extensive road network, with cars carrying about 90 % of passenger traffic. In 2019, 28 million people were transported in Spain by intercity buses between the Autonomous Communities. The largest value is typical for Madrid – 7.7 million passengers, which is more than the population of the region. This situation is natural given that Madrid is the capital of Spain, a cultural, tourist, economic and business center. In second place by this indicator is Castile-la-Mancha (5.8 million people). Given the fact that there are no significant airports in the region, and its administrative center Toledo is in close proximity to Madrid, this area has the largest flow of passengers. In third place is also the neighbouring region of Madrid, Castile and Leon (3.1 million passengers). More than 1 million passengers were transported by intercity buses in Andalusia, the Basque Country, Extremadura, Aragon, Valencia and Catalonia. Most of these are tourist regions and have significant flows of tourists, which explains this figure. More than 500,000 passengers used bus services in Cantabria, Murcia, Asturias and La Ríos, and the lowest rates were in Galicia and Navarre (260,000 and 111,000 respectively). For the Balearic Islands and the Canary Islands, this figure is not available at all, as it only includes traffic between the Autonomous Communities).

But if we talk about the average distance of transportation, then this figure will be the largest in Galicia and Navarre, (509 km and 426 km, respectively). Galicia is one of the most remote regions of the country, and Navarre is in the Pyrenees, so the distance will be the longest. Just over 300 km is the average distance travelled in Catalonia, Andalusia, Asturias and Valencia and 200 km each in Madrid and the Basque Country. It is the capital and coastal autonomous region, where many tourists are very mobile, and therefore often travel, and therefore the figure here will be higher than the average in Spain (190 km). In Murcia, Aragon, Castile and Leon, La Rios, Extremadura and Cantabria, the average distance for one passenger is 120–190 km. These regions are closer to the capital and the flow of tourists here is smaller compared to other regions. The lowest indicator in Castile-La Mancha is 57 km. As already noted, Toledo the administrative center of Castilla-La Mancha is in close proximity to Madrid and without its own airport.It is a major historical and cultural city. In addition to occupying a large area, Castilla-La Mancha borders Andalusia, Valencia and Aragon, which also reduces the average distance traveled.

In addition to regular intercity bus services for the needs of the population in Spain, there are various other carriers. In 2019, their total number was 68,894 units and most of them are taxis, or car rental companies (Fig. 4).

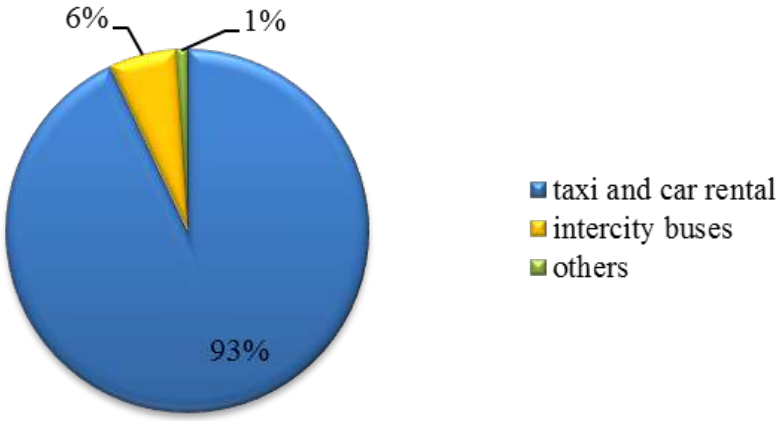


Fig. 4. Passenger carriers of Spain in 2019 (Renfe Operadora, 2020)

Spanish maritime transport has developed quite strongly due to its advantageous geographical location. For the most part, this applies to freight traffic, where the country is a leader among other European countries (in the top five), but in terms of passenger traffic, Spain also has a high rate (8th place in Europe). There are ports in all regions of Spain that have access to the Mediterranean Sea or the Atlantic Ocean. The largest number of ports is in Andalusia (Algeciras, Almeria Mortil, Malaga, Cadiz, Huelva and Seville, which is located on the River Guadalquivir, but can accommodate ships). There are 4 ports in Galicia (Ferrol-San Sibrao, La Coruna Vilagarcia, Vigo), three ports in Valencia (Valencia, Alicante, Castellon), two in Catalonia (Barcelona, Tarragona), Asturias (Aviles, Gijón) and the Canary Islands (Santa Cruz de Tenerife and Las Palmas). There is one port each in Cantabria (Santader), the Basque Country (Bilbao), Murcia (Cartagena) and the Balearic Islands (in Palma de Mallorca). There are also ports in Ceuta and Melilla (International Air Transport Association, 2020).

In 2019, 32.7 million passenger journeys were made by sea. Two thirds of the traffic is accounted for by cabotage and one third by international traffic (Fig. 5). Given that Spain has two island units and Ceuta and Melilla, which are located on the African continent, this figure corresponds to the passenger flow in the country. But international traffic is also important, as many cruise routes pass through Spain.

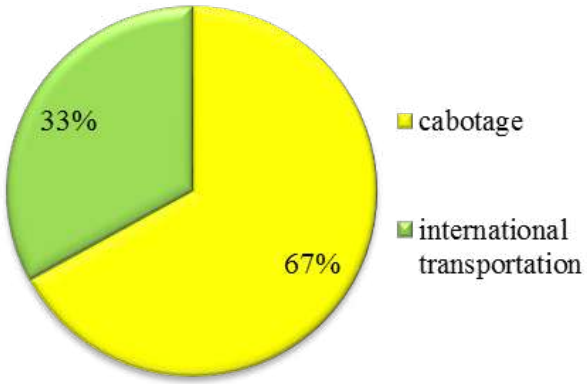


Fig. 5. The ratio of passenger transport by sea in Spain in 2019 (Renfe Operadora, 2020)

If we consider the transportation of sea passengers by region, the first places are occupied by Andalusia, the Canary Islands and the Balearics, as here are the largest ports in Spain in terms of passenger traffic. The islands are dominated by cabotage, and in Andalusia – international. In fourth place is Catalonia, where most of the traffic is in the port of Barcelona and a small share in Tarragona (dominated by international traffic). And in fifth place is Valencia, where the largest ports are Valencia and Alicante. Due to the large international traffic in the central city of Costa Blanca Alicante and cabotage traffic in the administrative center of the Valencia region, the overall ratio in the region is uniform. Other regions (Galicia, Cantabria, Basque Country and Murcia) have low sea passenger traffic (200–300 thousand passenger journeys each), and the lowest rate is in Asturias, despite the presence of 2 ports – 36 thousand passengers.

All international civil airports in Spain are subordinated to the public organization of Spanish Airports and Air Navigation Aena. There are 46 such airports in Spain and they are located in all regions of the country, as well as in Melilla. The largest number of airports is located in the Canary Islands – 8 units. In the Canary Islands, airports are located on all the 7 largest islands (Tenerife, Gran Canaria, Gomero, Hierro, Fuerteventura, Lanzarote, Palma). Tenerife has two international airports – Tenerife South and Tenerife North. The largest airport in the Canary Islands is Gran Canaria, which is located in Las Palmas de Grand Canaria. In second place after the Canary Islands in the number of airports is Andalusia – the second largest region and the first in population, in the south of Andasulia is one of the most popular tourist regions of the country (Costa de Almeria, Costa Tropical, Costa del Sol and the Costa de la Luz). There are 6 international airports in Andalusia (Almeria, Granada Hayen, Cordoba, Malaga, Seville, Jerez). The largest airport in the region is Malaga Airport.

There are 4 international airports in Catalonia, Castile and Leon and the Balearic Islands. The largest airport in Catalonia is Barcelona El Prat, it is the second largest in size and passenger traffic in Spain. Also in Catalonia, airports are located in Girona, Reus and Sabadell. Castile and Leon is the largest region in Spain, but given that it is located in the middle of the country and has no access to the seas and oceans; economically it is not very developed. The largest airport here is in the administrative center – Valladolid, there are also airports in Burgos, Leon and Salamanca. The largest airport in the Balearic Islands is the airport of the administrative center and the largest island – Palma de Mallorca. Among the four largest islands of the Balearic Islands (Mallorca, Menorca, Ibiza, Formentera), an airport is absent only on Formentera. On Mallorca, in addition to the main airport, there is also an airport in Palma de Mallorca, in Maracchi (San Bonet Airport). Taking into account the tourist flows, the airports of Ibiza and Menorca are quite large (Aeropuertos Españoles y Navegación, 2020).

Three international airports are located in the Basque Country and Galicia. The largest airport in the Basque Country is Bilbao Airport, which is the historic center of the region. The second largest airport is San Sebastian, and the airport of the administrative center of Vitoria-Gasteiz is only the third largest. The largest airport in Galicia is the administrative center of Santiago de Compostela, and the airports are located in the largest cities in the region – Vigo and La Coruna.

The most important characteristic of the airport infrastructure is the number of runways (defined rectangular section of the land aerodrome, prepared for landing and take-off of aircraft), as it determines the ability of the airport to receive aircraft at the same time. Their total number in Spain is 62. Another important technical (infrastructural) characteristic is the number of terminals for passenger service, of which there are 55 in Spain (Fig. 6).

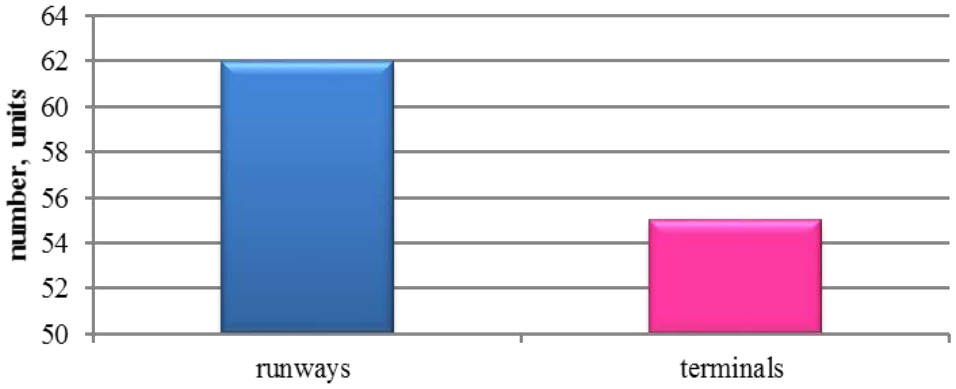


Fig. 6. Technical infrastructure of Spanish airports (Aeropuertos Españoles y Navegación, 2020)

Regular and charter flights to and from airports in Spain are operated by 163 airlines, which have connections with 358 cities in 121 countries. The largest number of airlines is represented in Barcelona – 90, in second place is Madrid-Barajas – 81. According to this indicator, Barcelona's leadership is due to the significant share of charter flights that take tourists to the resorts of the Costa Brava and Costa Dorada. In third place is the resort of Palma de Mallorca with 71 airlines. 58 airlines are represented at the largest airports in the Canary Islands – Gran Canaria and Tenerife South. Andalusia's largest airport, Malaga, has 53 airlines and another airport in the Canary Islands, Fuerteventura, has more than 50 airlines (52). More than 40 airlines are represented at the "resort" airports of Ibiza, Lanzaorote and Alicante, another 37 airlines operate in Menorca. The major cities of Valencia and Bilbao have 28 and 22 airlines, respectively. There are about 20 airlines operating fromAndalusia's Almeria and Seville airports, as well as at La Palma. 11–13 airlines are represented in Reus, Santiago de Compostela, Jerez, Tenerife North and Girona. More than 5 airlines operate at the airports of Asturias, Murcia, Santander, Zaragoza, Vigo, Granada Jaen and Valladolid. Two to four airlines are represented in La Coruna, Salamanca, Melilla, San Sebastian, Hierro and Pamplona. In the other 12 airports of the country there is only one airline.

From the country's largest airports, Madrid-Barajas and Barcelona, planes fly to the largest number of countries – 74 and 62, respectively. Therefore, the number of cities to which the aircraft travel is the largest – more than 200. In third place by these indicators is the airport of Palma de Mallorca, which connects with 174 cities in 30 countries.

Next is a group of "tourist" airports – Malaga, Gran Canaria, Tenerife South and Alicante, the planes of which have connections with 26–28 countries and 120–140 cities. From Valencia Airport, planes also fly to more than 20 countries, but the number of cities is much smaller – 83. There are connections between Fuerteventura, Lanzarote and Ibiza airports with more than 80 cities, Menorca has conections with 71 and Girona has connections with 50.

The number of countries of destination from each of these airports is 15–19, and all of them are also airports that serve tourist resorts. By air, Seville is connected with 65 cities in 14 countries. Slightly lower figures characterize another historical and cultural city of Spain – Bilbao 13 countries and 44 cities. The airports Almeria, La Palma, Santiago de Compostela, Santander, Reus, Asturias and Murcia each connect approximately 20–30 cities in about 10 countries, while 5–6 countries and more than 10 cities are connected by the airports of Jerez, Zaragoza, Albacete, Tenerife North and Vigo. Most flights from these cities are domestic flights.

Granada-Jaen, Salamanca, La Coruna, Vitoria and Pamplona airports are connected with the cities of 2–3 countries. Flights from Madrid-Cuatro Vientos, Valladolid, Melilla, San Sebastian Airport, Hierro, Badajoz, Sabadell and San Bonet only fly through Spain, but they have destinations in several cities. La Gomera, Leon, Lognoro-Agoncillo, Cordoba, Burgos and Huesca Pyrenees airports each fly to only one city in Spain.

In 2019, there were 22 airlines based in Spain, including 12 commercial airlines for passenger transport, companies that operate cargo flights, as well as companies that provide private charter flights. Spain's largest airlines are Iberia, Vueling Airlines, Volotea, Air Europa, Air Nostrum, Iberia Express, Binter Canarias, Air Europa Express and Wamos Air (Aeropuertos Españoles y Navegación, 2020).

Most airline headquarters are based in Madrid (8 units), 4 airlines are located in Barcelona, the Canary and Balearic Islands, another one is in Zaragoza and Valencia. As for hubs (transport operating hubs of airlines), the leader is also Madrid-Barajas (Fig. 7).

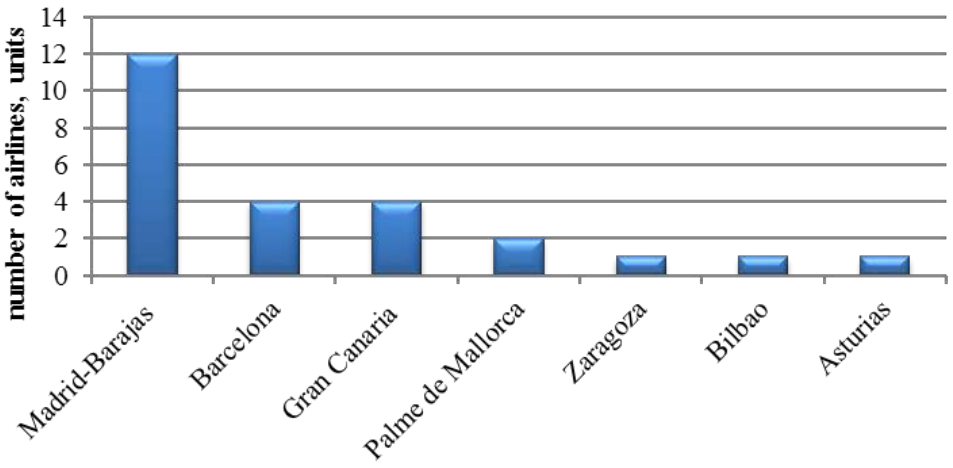
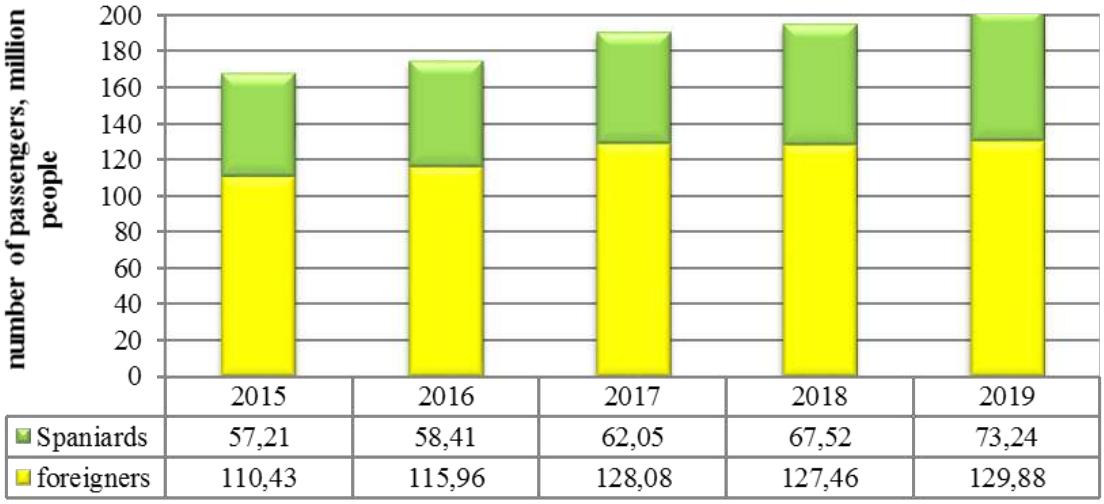


Fig. 7. Hubs of Spanish airlines
(La Sociedad Estatal de Infraestructuras del Transporte Terrestre, 2020; Ministerio de Fomento, 2020)

Transportation by air is constantly growing. This is influenced by factors such as increased tourist flows, the presence in the market of low-cost airlines (airlines that provide air passenger services at prices relatively lower than traditional airlines) and improving living standards.

In 2015, more than 167 million passenger journeys were made, in 2019 this figure was 203 million journeys, ie the volume of passenger traffic increased by more than 17 %. In the structure of traffic, international passengers are in the lead over the population of Spain (Fig. 8).



	2015	2016	2017	2018	2019
Spaniards	57,21	58,41	62,05	67,52	73,24
foreigners	110,43	115,96	128,08	127,46	129,88

Fig. 8. Passenger traffic at Spanish airports for the period 2015–2019
(Renfe Operadora, 2020)

Spaniards make up just over a third of all people served by airports (34–35 %) and this share has been constant over the last five years (Renfe Operadora, 2020). This ratio is explained by the size of the country and the lack of need of the indigenous population to use air transport, as well as tourist flows to the resorts of Spain, which create a significant share in passenger traffic.

The majority of passenger traffic on air transport is caused by tourist flows and this indicator is reflected in the monthly dynamics. The 5 months of the warm period of the year (May-September) account for more than 50 % of passenger traffic. The maximum value is typical for June and August – more than 27 million people. The minimum values are observed in January and February – 14 million people (Fig. 9).

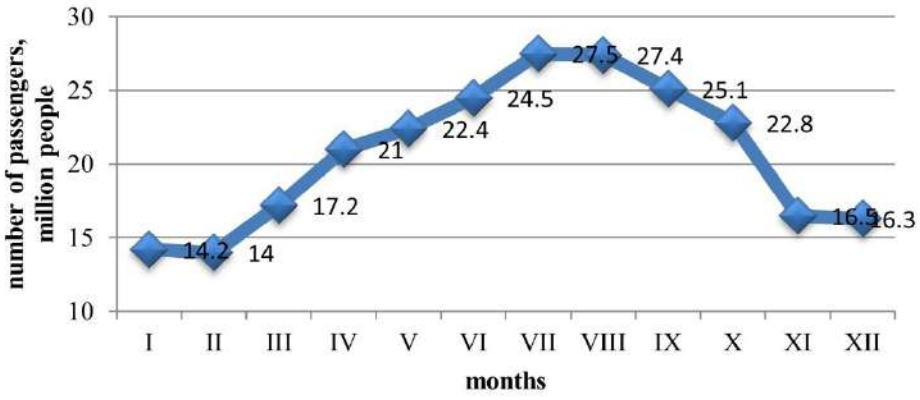


Fig. 9. Monthly dynamics of passenger traffic on Spanish air transport in 2019 (Renfe Operadora, 2020)

The analysis of the components of the transport infrastructure of Spain by individual modes of transport made it possible to identify the uneven development in the regions of the country. In order to assess the level of development of Spain's transport infrastructure for tourism, the method of scoring will be the most appropriate. This technique is widely used in tourism and geographical research.

Theoretical principles for scoring are covered in the work of O. O. Beidyk (Beidyk, 2001). The scientist notes that the evaluation score is the ordinal number of a group of phenomena, processes, objects that are ranked, limited by certain limits of their intensity or manifestation. Under the score scale, the author proposes to understand the quantitative classification or division of certain phenomena, processes or objects that are continuously and gradually increasing or decreasing into groups.

Points can be:

a) integers, when they are set, are assigned (simple points);

b) any real numbers, when they are calculated as a percentage of the maximum value (complex points) (Beidyk, 2001).

It is necessary to distinguish scores from measurements expressed in points. Score scales are used not only in the assessment of any phenomena and properties (often qualitative) of certain objects, but also in the measurement – in the quantitative expression of the degree of their manifestation. Therefore, there are evaluation scores and "measuring" scores (the concept of "measuring" score is conditional) (Beidyk, 2001).

The application of the scoring methodology was used to analyze the level of development of transport infrastructure for the needs of tourism in the regions of Spain. The expediency of this technique is that it allows you to evaluate indicators that cannot be estimated using absolute quantitative values, as well as to compare the phenomena characterized by different units.

The scoring process consists of five stages:

1. Definition of evaluation indicators – signs (factors) by which the level of development of transport infrastructure will be estimated;

2. Development of evaluation scales, including the selection of evaluation criteria for each indicator of the studied phenomenon, determination of the factor load (significance coefficients) of each indicator in the form of an evaluation factor table;

3. Obtaining individual assessments of specific indicators (factors) on the basis of developed criteria;

4. Obtaining general (integrated) assessments;

5. Analysis of the obtained estimates and ranking of the regions of Spain by the level of development of transport infrastructure for tourism.

To score the level of development of transport infrastructure in Spain for tourism, 20 indicators were selected, which are divided into 4 groups (Table 1).

The first group consists of five indicators that characterize the infrastructure of road transport, the second group – three indicators that characterize rail transport, the third group consists of one indicator of the number of seaports (sea transport), the fourth group includes five indicators that characterize air transport infrastructure and the fifth group of indicators characterizes passenger traffic. These indicators are divided into a separate group, as the volume of passenger traffic is directly proportional to the quality of transport infrastructure and characterizes its ability to receive passengers, most of whom are tourists.

Taking into account the provided factor load on each indicator, the maximum total score that is possible in the categories "Road transport" is 20, "Railway transport" – 13, "Sea transport" – 8, "Air transport" – 20, "Passenger transport" – 20 The maximum possible score is 81. This distribution of points and factor load reflects the importance of a particular mode of transport in the structure of passenger traffic and the attractiveness of use for tourists. The maximum number

Table 1. Estimation factor table of indicators of the level of development of the transport infrastructure of Spain for the needs of tourism

Indicator, units of measurement	Factor load	Conditions for evaluating the indicator in points					
		5	4	3	2	1	0
1.1. Length of highways, km	0.8	> 20000	10000–19999	5000–9999	1000–4999	< 999	
1.2. The share of motorways in the total length of roads,%	0.8	> 15.0	10.0–14.9	7.0–9.9	5.0–6.9	< 4.9	0
1.3. Density of highways, km/km^2	1	> 0.60	0.50–0.59	0.40–0.49	0.30–0.39	< 0.29	0
1.4. Carrier companies (taxi and car rental), units	0.8	> 10000	5000–9999	1000–4999	100–999	< 99	
1.5. Carrier companies (intercity buses), units	0.6	> 500	300–499	100–299	50–99	< 49	
2.1. Length of railways, km	1	> 2000	1000–1999	500–999	200–499	< 199	0
2.2. The share of electrified railways in the total length of railways,%	0.6	100	80–99	60–79	50–59	< 49	0
2.3. Density of railways, km/thousand km^2	1	> 70.0	50.0–69.9	40.0–49.9	20.0–39.9	< 19.9	0
3.1. Number of seaports, units	1.6	> 5	4	3	2	1	0
4.1. Number of airports, units	1	> 5	4	3	2	1	
4.2. Number of terminals, units	0.6	> 9	7–8	5–6	3–4	1–2	
4.3. Number of airlines, units	0.6	> 80	60–79	40–59	10–39	< 9	
4.4. Flight directions (countries), units	1	> 50	20–49	10–19	5–9	< 4	
4.5. Flight directions (cities), units	0.8	> 200	100–199	30–99	10–29	< 9	
5.1. Number of passengers transported by intercity buses (between autonomous districts), thousand people	0.6	> 5000	2000–4999	1000–1999	500–999	< 499	0
5.2. Number of passengers transported by city bus, million people	0.6	> 300	200–299	100–199	50–99	< 49	
5.3. Number of passengers transported by rail, thousand people	0.8	> 100000	50000–99999	10000–49999	1000–9999	< 999	0
5.4. Number of passengers transported by sea, thousand people	0.8	> 5000	2000–4999	1000–1999	100–999	< 99	0
5.5. Number of passengers transported by air, thousand people	0.6	> 50000	10000–49999	1000–9999	100–999	< 99	
5.6. Share of international air transport,%	0.6	> 80.0	50.0–79.9	20.0–49.9	10.0–19.9	< 9.9	

of points scored by the regions of Spain is 63.2 points, the minimum – 15.0 points. Taking into account the following indicators, all administrative units of Spain are divided into 5 groups according to the level of development of transport infrastructure for tourism (Fig. 10):

1. Highest – more than 50 points (3 regions);
2. High – 40–49 points (5 regions);
3. Sufficient – 30–39 points (6 regions);
4. Average – 20–29 points (3 regions);
5. Low – less than 19 points (1 region).

That is, almost 80 % of the administrative-territorial units of Spain have high scores for transport infrastructure, which in turn is one of the main factors in the development of tourism in the country.

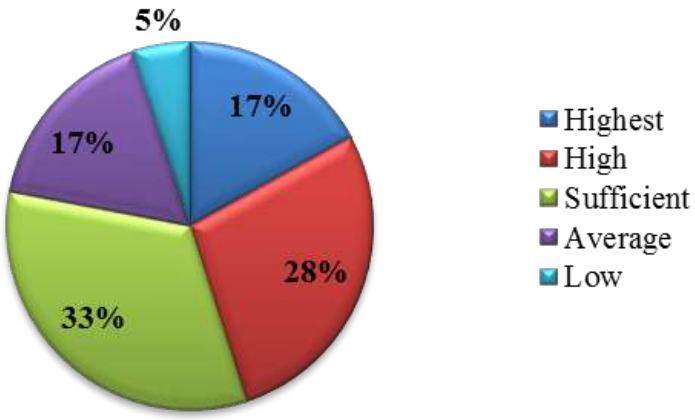


Fig. 10. Ratio of Spanish regions in terms of the level of transport infrastructure development for tourism needs

Assessing the current state of development of transport infrastructure for tourism, we can say that the infrastructure is most developed in the tourist regions of the country – Catalonia, Andalusia, Madrid, the Canary and Balearic Islands, as there is a need to constantly update and develop it to attract more tourists, who contribute to the country's GDP.

Conclusions.

The modern transport infrastructure of Spain has undergone a long period of development. The network of highways was most developed in the twentieth century. The history of railways in Spain begins in the nineteenth century with the construction of the first railways and continues to this day, making it one of the most important elements of society and economies in Spain. Occupying a favourable geographical position, Spain has always been one of the first places in the world for the development of maritime transport. The rapid development of air transport is one of the most characteristic elements of the recent evolution of the Spanish transport system. As of 2019, the total length of Spanish railways was 15,931.08 km, two-thirds of which are electrified. The greatest length of the railways is in the largest regions of Spain: Castile and Leon, Andalusia, Castile-La Mancha. The share of electrified railways is particularly high in Catalonia, where the railroad runs along the Mediterranean resorts of the Costa Brava. Spain currently has more than 1,500 km of high-speed rail lines connecting Madrid with Malaga, Seville, Valencia, Barcelona, Valladolid, Tarragona, Zaragoza, Alicante and Ferroli. The largest amount of traffic is to Madrid and Catalonia – about 79 % of all traffic by rail (more than 240 million passenger journeys each). Here are the largest cities in Spain, and Catalonia is also a tourist region. Rail transport infrastructure is well developed in the country, but given the short distances across the country, rail transport is not as popular as road transport.

In 2019, the total length of roads in Spain was 165,484 km. The Spanish road network is mainly centralized in 6 directions, connecting Madrid with the Basque Country, Catalonia, Valencia, Andalusia, Extremadura (roads towards Portugal) and Galicia. In addition, highways run along the Atlantic and Mediterranean coasts. Carriage of passengers by car accounts for about 90 % of traffic. For the needs of the the population of cities and tourists, the number of which is annually greater than the population of the country, Spain has an extensive network of urban transport and intercity bus transport. In addition to regular intercity bus services for the needs of the population in Spain, there are various other carriers. In 2019, their total number was 68,894 units and most of them are taxis, or car rental companies. Road transport is very popular in Spain.

Maritime passenger transport has become more developed in Spain on the Mediterranean coast due to cruises and internal transport to the island autonomous districts. In 2019, 32.7 million passenger journeys were made by sea. Two-thirds of shipments are for cabotage and one-third for international traffic. According to 2019, the largest number of traffic falls on the port of Balearic Islands in Palma de Mallorca in the Balearic Islands. This is followed by the port of Andalusia Algeciras and the port of Santa Cruz de Tenerife in the Canary Islands. Together, these three ports account for more than 50 % of passenger traffic by sea in Spain.

The country's largest airports are Madrid Barajas and Barcelona El Prat, which are located in the country's largest cities. Slightly smaller airports are the so-called "tourist" airports – Malaga, Palma de Mallorca, Gran Canaria, Alicante and Tenerife South. They serve tourist resorts and have a well-developed infrastructure. In total, from the airports of Spain you can reach 358 cities in 121 countries. The largest loads fall on the regions of Madrid, Catalonia, the Canary Islands, the Balearics, Andalusia and Valencia, which serve more than 90 % of air passengers.

On the basis of quantitative indicators of the analysis of the transport infrastructure of Spain, a point assessment of the level of development of the transport infrastructure of the regions of Spain for the needs of tourism was carried out. Administrative units are divided into 5 groups: with the highest, high, sufficient, average and low level of development of transport infrastructure for tourism. Transport infrastructure is most developed in the tourist regions of the country – Catalonia, Andalusia, Madrid, Canary and Balearic Islands, as there is a need to constantly update and develop it to attract more tourists, who contribute to the country's GDP.

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Investigation of buffer capacity of the recreational environmental through the self-purification of natural-technogenic hydroecosystems in the Carpathian region

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Abstract. The aim of research was to investigate the theoretical and practical aspects of the buffer capacity of the recreational environment of the Carpathian region of Ukraine through the improvement of self-purification assessment on the example of natural-technogenic hydroecosystems. Studies of the self-purification process were carried out on the example of the right tributaries of the river Svicha in the Carpathian region, which are water intakes of wastewater from the oil and gas industry enterprise of Ivano-Frankivsk region. The main factors influencing the natural process of self-purification of natural watercourses are determined. As a result, the indicator of wastewater dilution intensity was improved with the substantiation of the proposed coefficients, which depend on the value of the river flow velocity and water temperature. A scale for assessing surface waters has been developed, that allows to determine the degree of natural self-purification of water from pollutants. Based on the results of the analysis of selected water samples, the pattern of self-purification of natural watercourses from oil products is obtained, which will allow to make forecast maps of the buffer capacity of the recreational environment of the Carpathian region. A regression analysis was performed, which proves the relationship between the content of petroleum products and the distance of their distribution from the source of pollution in the Lushchava River. Fisher's F-test was used to check the significance of the dependence. The reliability of the relationship between the indicators is confirmed by the coefficient of determination ($D = r^2$), which is 0.96. Summarizing the results of the study the scale of estimation of natural self-purification of surface waters from pollutants depending on the calculated indicator of wastewater dilution intensity which's criteria are the accounting for speed of a river flow and a temperature mode is offered. When establishing the range of n values, the average value of the calculated indicator of the intensity of wastewater dilution for the studied rivers, which is 4, was taken into account. As a result, the proposed scale of assessment of natural self-purification of surface waters allows to determine the degree of self-purification of the right tributaries of the river Svicha, which is necessary for further forecasting of water pollution in the Carpathian region.

Ключові слова: recreational environment, hydroecosystem, degree of self- purification, dilution index

Дослідження буферної здатності рекреаційного середовища через самоочищення природно-техногенних гідроекосистем в Карпатському регіоні

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Анотація. Метою дослідження було дослідити теоретичні та практичні аспекти буферної ємності рекреаційного середовища Карпатського регіону України шляхом вдосконалення оцінки самоочищення природно-техногенних гідроекосистем. Дослідження процесу самоочищення проводилось на прикладі правих приток річки Свіча в Карпатському регіоні, які є водозаборами стічних вод підприємства нафтогазової промисловості Івано-Франківської області. Визначено основні фактори, що впливають на природний процес самоочищення природних водотоків. В результаті, показник інтенсивності розбавлення стічних вод був покращений обґрунтуванням запропонованих коефіцієнтів, які залежать від величини швидкості течії річки та температури води. За результатами аналізу відібраних проб води отримано закономірність самоочищення природних водотоків від нафтопродуктів, що дозволить складати прогнозні карти буферної ємності рекреаційного середовища Карпатського регіону. Проведено регресійний аналіз, який доводить взаємозв'язок між вмістом нафтопродуктів та відстанню їх розподілу від джерела забруднення в річці Лущаві. F-тест Фішера використовувався для перевірки значимості залежності. Надійність взаємозв'язку між показниками підтверджується коефіцієнтом детермінації ($D = r^2$), який дорівнює 0,96. Узагальнюючи результати дослідження, пропонується шкала оцінки природного самоочищення поверхневих вод від забруднюючих речовин залежно від розрахункового показника

інтенсивності розбавлення стічних вод, критеріями яких є врахування швидкості течії річки та температурного режиму. При встановленні діапазону значень n було враховано середнє значення розрахункового показника інтенсивності розведення стічних вод для досліджуваних річок, яке становить 4. У підсумку, запропонована шкала оцінки природного самоочищення поверхневих вод дозволяє визначити ступінь самоочищення правих приток річки Свічі, який необхідний для подальшого прогнозування рівня забрудненості водних об'єктів Карпатського регіону.

Ключові слова: рекреаційне середовище, гідроекосистема, ступінь самоочищення, показник розбавлення.

Introduction.

The concept of buffering capacity of hydroecosystems logically follows from their essence and features (Prykhodko et al, 2020, Kresić, Stevanović, 2010). Hydroecosystems have evolved over millions of years, and cyclical exchange is maintained both internally and externally as a component of larger ecosystems (Khilchevskyi et al, 2018). Ecological cycles are characterized by continuous fluctuations of their variable characteristics (Mandryk et al, 2017). When changing conditions disrupt any connection in the hydroecosystem, the whole cycle behaves as one self-regulating system with feedback, and soon, the situation returns to equilibrium (Rajchel, Czop 2013). Since such disturbances occur all the time, the variables of hydroecosystems fluctuate continuously. In a natural hydroecosystem, all ecological fluctuations occur within acceptable limits of homeostasis (restoration of equilibrium) (Bouman, 2014). In a man-made system there is a danger that with the fluctuations beyond acceptable limits, the system will not be able to compensate for the disturbance (Shmandiy et al, 2017). The scope of permissible fluctuations of ecological cycles is the flexibility of the hydroecosystem (Shkitsa et al, 2020). Lack of flexibility is a lack of "health" of the hydroecosystem, which means the potential of the buffer capacity or hydroecological potential (Eigen, Schuster, 2012).

The ecological sustainability of the hydroecosystem depends on the limited resource base (quantitative and qualitative potential) and on its diversification (diversity), that is, on the magnitude. The more diverse the hydroecosystem, the more diverse the relationship it is able to maintain if one connection is broken (Chelmicki *et al,*2011).

It is obvious that the hydroecological potential is restored due to the variable processes of the cycle of matter and the processes of self-purification (Karpinski et al, 2018,). Hydroecological potential of the local hydroecosystem to assess the impact of man-made activities is extremely important, because the processes at this level are a continuous course of environmental disturbance by human economic activity (Kinash et al, 2019, Simkiv et al, 2021). Variable components at this level are highly dependent on climatic, physical-geographical and other environmental conditions (Staśko, Buczyński, 2018). In addition, local discharges into water bodies are the anomalies for the hydroecosystem.

In resource terms, hydroecological potential means the part of water resources that can be used by the national economic complex while maintaining environmental safety and balanced water use in natural and man-made hydroecosystems (i. e. man-made activities ensure sustainable development while minimizing disturbances of hydroecosystems to the limit).

Thus, the following question arises: at what level balanced water should be considered? There is no doubt that specific quantitative parameters of the balance can be obtained by identifying hydroecosystems at different levels of detalization. One can agree with the authors (Odnorih et al, 2020) of the opinion that humanity, as a whole, consumes an insignificant share of hydrosphere resources (the available volume of fresh water used by mankind is about 0.5 %), without changing the volume of the water cycle in nature. The duration of the biological cycle of the main, most common heavy metals in the geological history is negligible and is in the range of 5–100 years. That is why human activity within the hydrosphere over a 100-year time interval can be considered as part of a balanced closed cycle. In this case, the mechanism of inertia of metabolic processes that are continuous in the hydrosphere, only delay the process of restoring quality, but do not change it (Stevens et al, 2011).

The aim of research was investigat the theoretical and practical aspects of the buffer capacity of the recreational environment of the Carpathian region of Ukraine through the improvement of self-purification assessment on the example of natural-technogenic hydroecosystems.

Materials and methods.

Further studies of the self-purification process were carried out on the example of the right tributaries of the river Svicha in the Carpathian region, which are water intakes of wastewater from the oil and gas industry enterprise OGPD "Dolynanaftogaz" Ivano-Frankivsk region.

After analyzing the statistical reports of the enterprise on hydrochemical monitoring of surface waters, wastewater contains the following chemicals: chlorides, nitrates, nitrites, ammonium nitrogen, ammonium salt, sulfates, phosphates, BOD_5, suspended solids, petroleum products. Most of the wastewater contains organic substances, as the quality of wastewater is formed from industrial, domestic and rainwater of auxiliary structural units of OPGD "Dolynanaftogaz".

After the discharge of return wastewater of the enterprise into surface waters, first there is a process of mixing and dilution of polluted wastewater with river water. If we study the concentration of a specific pollutant in wastewater and directly in river water, their values usually differ. The rate of reduction of the impurity content in the water depends on the concentration of the pollutant in the wastewater.

The indicator of wastewater dilution intensity is determined with the formula (Karpets, 2014):

$$n = \frac{Co - Cw}{C - Cw} \quad (1)$$

where C_0 is the concentration of pollutant contained in wastewater discharged into natural streams, mg/dm^3; *Cw* and *C* – the concentration of pollutants in the reservoir before and after release, respectively, mg/dm^3.

The study of the database of ecological monitoring of surface waters revealed exceeding the maximal allowable concentration for nitrogen-containing compounds, chlorides, BOD_5 (biochemical oxygen demand for 5 days). Therefore, to track the dynamics of changes in chemicals in the background and 500 m below the discharge of wastewater, calculations were performed to determine the intensity of dilution of wastewater specifically for those chemical compounds that exceed the standard of maximum permissible concentration (MPC) (Gomelya et al, 2019).

Because the content of petroleum products in the water of the right tributaries of the river Svicha is within the norm (not more than 0.05 mg/dm^3), the dilution intensity for petroleum products was not calculated.

Results.

The average value of concentrations of chemical elements in the discharge of wastewater into natural watercourses, as well as 500 m above and 500 m below the discharge No. 1, 2, 3, 4 was calculated on the basis of quarterly environmental surface water monitoring data (Hryniuk V. I., 2018).

During the calculation of the water dilution intensity index, negative values were found in the Turianka and Lushchava rivers, which indicates that the value of the pollutant concentration exceeded 500 m above the issues No 1; 3 (Table 1).

As a result, the average annual intensity of dilution of pollutants in the right tributaries of the river Svicha was calculated, which characterizes how the concentration of these substances in the calculated line of the river decreased relative to its concentration in wastewater (Table 1). In this case, the highest average annual intensity of wastewater dilution for the river Sadzhava (4.1), the lowest – for the river Turianka (1,2).

Table 1. The average annual change in the intensity of dilution of pollutants in the right tributaries of the river Svicha

Water body	r.Turianka	r.Sadzhava	r.Lushchava
Cl^- (chlorides)	4.0	4.4	0.22
NH_4^+ (Ammonium)	1.1	2.7	8.4
NO_2 (Nitrite)	0.4	1.4	-0.28
BOD_5 (biochemical oxygen demand for 5 days)	–0.9	9.3	0.7
ammonium nitrogen	1.4	2.8	5.2
n	1.2	4.1	2.8

The disadvantage of this indicator is that in its calculation only the concentrations of chemicals in wastewater and natural watercourses are taken into account. Other factors influencing the process of dilution of contaminated water are not considered.

The main factors that affect the intensity of surface water self-purification include: morphometric characteristics (flow velocity, river depth), hydrological regime, climatic conditions, relief, location of natural watercourses (geographical factor); condition of soils and vegetation; the impact of human activities (the presence of enterprises, unauthorized discharges of waste near natural watercourses).

Indicator of the intensity of dilution of wastewater is proposed to improve by taking into account hydrometeorological factors (Mandryk et al, 2020). The improved indicator differs in that coefficients are taken into account, which depend on the value of the river velocity and water temperature.

$$n = \frac{Co - Cw}{C - Cw} \cdot k_V \cdot k_t \quad (2)$$

де k_V – the proposed coefficient, the value of which depends on the speed of the river;

k_t – the proposed coefficient, the value of which depends on the water temperature.

The value of the coefficients is based on the calculations performed by the formulas:

$$k_V = \frac{V}{V_c} \quad (3)$$

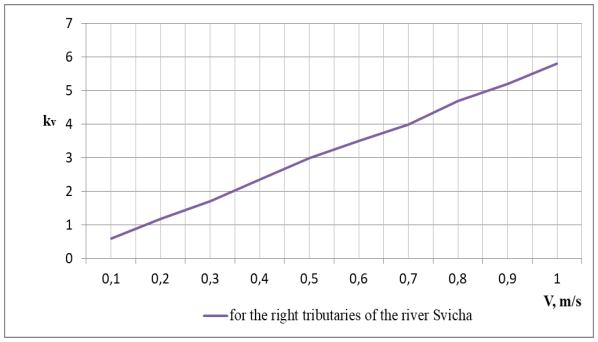
$$k_t = \frac{t}{t_c} \quad (4)$$

where *V* – the specified speed of the river, m/s; *Vc* – average velocity of the right tributaries of the river Svicha, m / s; *t* – specified water temperature, °C;

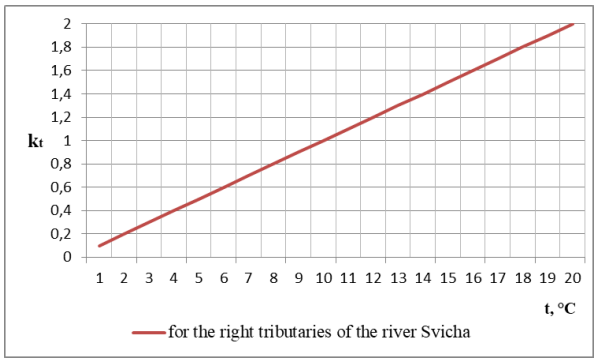
t_c – the average annual water temperature of the right tributaries of the river Svicha, °C.

The ranges were selected on the basis of the analysis of current velocities and average annual water temperature indicators for small and large rivers of Ukraine.

The chartes of dependence of k_v on the flow velocity and k_t on the average annual temperature have been created, provided that the average water flow velocity for the right tributaries of the river Svicha is 0.17 m/s, the average annual water temperature is 10 °C (Fig. 1).



a)



b)

Fig.1. Dependence of k_V on the flow velocity (a); k_t from the average annual water temperature of the right tributaries of the river Svicha (b)

Based on the obtained diargams of the dependences of the proposed coefficients on hydrometeorological parameters, the values of k_V and k_t for the rivers Turianka, Sadzhava and Lushchava were obtained:

if V = 0.17 m /s, then k_V= 1 (for the river Turianka);

if V = 0.24 m/s, then k_V = 1.4 (for the river Sadzhava);

if V = 0.1 m/s, then k_V = 0.7; (for the river Lushchava);

if t = 10 °C m/c, then k_t = 1.1 (for the right tributaries of the river Svicha).

The calculation of indicators of wastewater development intensity coming to the right tributaries of the Svicha River was carried out (Table 2).

Table 2. The results of the calculation of the indicator of the intensity of wastewater of OPGD "Dolynanaftogaz"

Water body	*n* considering k_V and k_t
r. Turianka	1.3
r. Sadzhava	6.3
r. Lushchava	2.1

Summarizing the results of the study the scale of estimation of natural self-purification of surface waters from pollutants depending on the calculated indicator of intensity of dilution (n) of sewage which criteria are the account of speed of a river flow and a temperature mode is offered (Table 3). When establishing the range of values of n, the average value of the calculated indicator of the intensity of wastewater dilution for the studied rivers, which is 4, was taken into account.

Table 3. Scale for assessing the natural self-purification of surface waters from pollutants

Range of n values	Degree of self-cleaning
n< 1	Low intensity
1< n <2	Low intensity
2< n <4	Medium intensity
4< n <6	Moderate
n >6	High intensity

According to the proposed scale of surface water assessment, the degree of self-purification of water for the right tributaries of the Svich River is determined within the influence of oil and gas companies:

Turianka River – low intensity (n = 1.3);

Sadzhava River – high intensity (n = 6.3);

Lushchava River is medium-intensive (n = 2.1).

As a result, it was determined that the river Sadzhava has the greatest ability to natural self-purification, as the multiplicity of dilution of wastewater is 6.3.

An emergency situation occurred within the territory of the oil and gas company (2017), as a result of which oil pollution of the Lushchava River occurred. Therefore, field studies of this area were conducted and 10 water samples were taken to study the self-purification properties of the Lushchava River from pollutants.

As a result of the analysis of the taken samples of water it is established that the value of concentration of oil products fluctuates within 3.5–8 mg/dm^3 that in 70–160 times exceeds admissible norms (at maximum concentration limit of 0.05 mg/dm^3) (Shkitsa et al, 2020).

A regression analysis was performed, which proves the relationship between the content of petroleum products and the distance of their distribution in the Lushchava River.

Fisher's F-test was used to verify the significance of the relationship (Toms, Lesperance, 2003). The reliability of the relationship between the indicators is confirmed by the coefficient of determination ($D = r^2$), which is 0.96.

The functional dependence (Fig. 2) of the process of self-purification of surface water from petroleum products, which is described by the equation, was established:

$$C(n) = (8–0.008 \cdot L)/(1–0.0007 \cdot L) \quad (5)$$

where $C(n)$ – concentration of oil products, mg/dm^3; L is the distance from the source of pollution, m.

Based on the proposed level of self-purification of water, it was determined that at a distance of 1135 m the content of petroleum products within will reach the standard MPC.

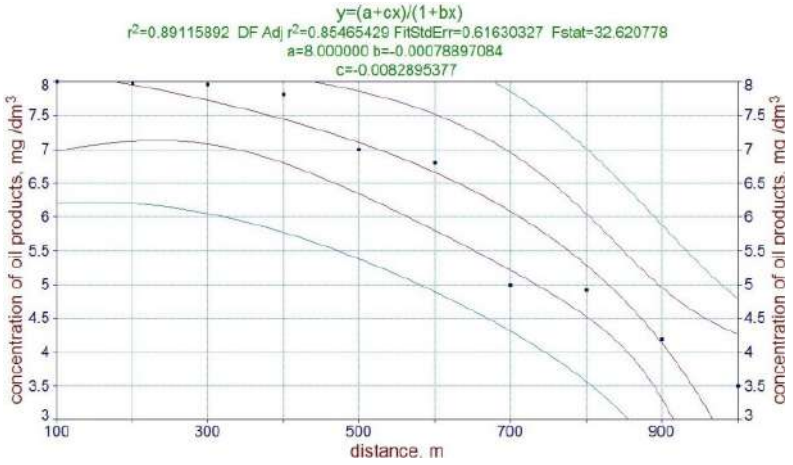


Fig.2. Functional dependence of surface water self-purification process on oil products

Discussion.

The presence of positive hydro-ecological potential, which, according to the authors, is directly proportional to the natural and man-made safety of the hydro-ecological environment and its components, determines the ability to restore its own structure and functions of hydro-ecosystems.

The balance of the hydrosphere is determined by the continuous cycle of matter and energy in all its components. The hydrosphere is an integral, self-organizing dynamic system (Rosenberg, Smelyansky 2005, Framework Directive 2000/60/EC "On the establishment of a framework for Community action in the field of water policy"). River hydroecosystems have the greatest ability to restore quickly their hydroecological potential.

The law of balanced nature management was first derived in 2000 by I. Yhnatov, A. Kokin (Yhnatov, 2000). Its content is as follows: in the transition to sustainable development, the rate of economic growth must be balanced with the rate of restoration of natural resources and the rate of restoration of the quality of the natural environment within the assimilation potential of nature (Arkhypova L, 2019, Kravchynskyi, 2021). According to the authors of the law, in the case of non-renewable resources, it is necessary to comply with the conditions of deductions for the replacement of other resources, with new properties that meet the requirements of advanced technology.

The application of the law of balanced nature management to natural-technogenic hydroecosystems – components of the recreational environment, from the point of view of the authors may be as follows.

If within a separate natural and man-made hydroecosystem such a level of water use and water consumption is achieved due to the growth of water abstraction and "dirty" technologies, when the assimilation function of the recreational environment will not cope with the reproduction of resources and environmental quality (will not keep pace with economic growth inertia), there will be a need to maintain the quality and resource status of natural and man-made hydroecosystems through additional costs for its reproduction by reducing living standards. Further increase in the load on the recreational environment will be meaningless.

There are several scenarios.

The first scenario – to reduce the rate of water consumption, while reducing the rate of waste production, while maintaining "dirty" production to a level where the natural man-made hydroecosystem

will cope with waste itself (fit the rate of economic growth in the rate of assimilation potential of nature), and the circulation of the substance will provide the quality of the recreational environment necessary for human existence. But then we need to "forget" about development, and even more sustainable.

The second scenario – to leave the rates (even small) of consumption of water resources satble in time, it will make possible to reduce waste and discharges due to improvement of production technologies. In this case, we can count on the time-limited potential for economic growth, as the problem of water scarcity arises again in the future.

The third scenario is to achieve compliance of economic growth rates with the rates of reproduction of quantitative and qualitative components of hydro-ecological safety. An imaginary balance is created, which contains a number of uncertainties. The first is what should be the marginal rate of economic growth? Second, from which state of the hydroecosystem should the implementation of the scenario of balanced development begin?

The fourth scenario includes the achievement of compliance of economic growth rates with the rate of reproduction of quantitative and qualitative indicators of water resources within the hydro-ecological potential of the hydro-ecosystem on the basis of natural and man-made safety of hydro-ecosystems. This is the only scenario that satisfies sustainable development models.

However, there is the question: how to estimate the value of the regenerative properties of hydroecosystems?

The second part of the article is devoted to the attempts to quantify the regenerative (self-purification) properties of natural and man-made hydroecosystems within the recreational environment of the Carpathian region with the available oil and gas production (Zasidko et al, 2020).

Oil and gas companies use large amounts of water in their production processes, which are reused or diverted to natural watercourses after treatment. Typically, companies control the quality of wastewater when discharged into rivers, as well as at a distance of 500 m above and 500 m below the discharge of wastewater. However, it is important to have information on the ecological condition of the river in general, potential sources of pollution and natural self-purification of surface waters. The main pollutants in the oil and gas industry are petroleum products.

Peculiarities of surface water pollution by oil products and self-purification of water from pollutants were studied by M. R. Maksymyuk et al. (2014), O. M. Krainyukov (2007), Gololobova, Dorogan, (2019), Rogowska et al (2020), Likhovid, E.G. et al.(2002), Malovanyy et al (2019), Bakar, Khalil, (2016), Survilė, O.; Šaulys, V., Stanionytė, A. (2017), Tien Zubaidah, Nieke Karnaningroem, Agus Slamet (2019), Aleksashkin, I.V., Pershina, E.D. ets.

The study of hydrochemical processes that occur in small rivers during the discharge of insufficiently treated return water is given much less attention than the study of water quality in large rivers. Since small rivers are a kind of "water capillaries", the quality of which depends on the ecological status of the entire river system, it is especially important to study the process of self-cleaning of small rivers within the influence of oil and gas industry.

The most important feature of surface runoff is the ability of the water flow to self-purification and the biological balance establishing. The process of self-purification of watercourses is a very important natural phenomenon. Natural self-purification occurs due to biological, physical and chemical processes that lead to a decrease in the concentrations of pollutants. Mixing and dilution of pollutants to certain concentrations and their subsequent oxidation, destruction and transformation are the only mechanism of self-purification, and such processes are necessary components. Their joint action causes the "processing" of foreign substances and at certain loads eliminates their accumulation in the reservoir and maintaining the concentration below the permissible level (Kinash et al, 2019).

Conclusions.

Thus, the theoretical and practical aspects of the buffer capacity of the recreational environment of the Carpathian region of Ukraine by improving the assessment of self-purification on the example of natural and man-made hydroecosystems have been studed. The main factors influencing the natural process of self-purification of natural watercourses are determined.

As a result of the study of water quality parameters of the right tributaries of the river Svicha, the maximal permissible concentration for the following pollutants was revealed: chlorides, ammonium salts, nitrites, ammonium nitrogen and biochemical oxygen consumption (BOD_5).

The intensity of wastewater dilution intensity has been improved by taking into account coefficients, the value of which depends on hydrometeorological factors, such as: river flow velocity and water temperature. A scale for assessing the natural self-purification of surface waters has been developed, which allowed to determine the degree of self-purification of the right tributaries of the Svicha River from pollutants: for Turianka (low intensity), Lushchava (medium intensity) and Sadzhava (high intensity).

Field researches of water quality of Lushchava river on the content of oil products as a result of emergency situation are carried out. Based on the laboratory analysis of the selected water samples, the content of oil

products was exceeded by 70–160 times in comparison with the standard of MPC (0.05 mg/dm^3). The distance at which the content of oil products in the water of the Lushchava River reaches the maximum allowable concentration (1135 m) is calculated.

Thus, the pattern of self-purification of natural watercourses from oil products is obtained, which will allow making forecast maps of the buffer capacity of the recreational environment of the Carpathian region in case of emergency oil spills.

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Approaches to organize the econetwork of the Transnistria region in the conditions of urban landscape

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Abstract. The article focuses on the relevant topic of the development of the ecosystem consisting integral landscape formations of biocentric-network type, which has been done in many countries of Europe since the 1990s. The article emphasizes certain achievements of independent Ukraine regarding the methodological developments of the concept of ecosystem, first of all at the national and regional levels and also the low level of its introduction at the local level. In the process of performing (based on studying foreign and domestic experiences) the scientific study of development and perspectives of the development of local ecosystem of a residential area as a basis for the regional ecosystem in the conditions of Yampil city of Vinnytsia Oblast, we determined its extremely high biotic and landscape diversities, and also the threats of its significant transformation. As an important step to prevent negative influence of agrarian activity of inhabitants of Yampil on the environment with restoration of diversity it is characteristic of, we considered the development of the city`s ecosystem. The scientific substantiations made by applications of tools became the basis for the development of local ecosystem.

In the developed scheme "Local ecosystem of Yampil city", we indicated the structural elements of the ecosystem, their localization, toponyms, made corresponding indications on the map and provided all its elements with descriptions. The key and connective territories of the local ecosystem of Yampil city are compartmentalized based on the adopted criteria of the selection. Their internal structures that we characterized in details allowed us to assess the special roles of the key and connective territories in the preservation of biodiversity, landscape basics of the formation and further development of Yampil city. The territories of the city which were not included in the local elements of the ecosystem are considered restorative and buffer territories within the local and regional ecological networks. The suggested scheme of the local econetwork is basic concerning the implementation of the following stages of the development of the ecosystem by composing schemes at the regional and general national levels and is the main condition for the balanced development of the Transnistria region. We obtained the results so as to preserve and effectively use the biotic and landscape diversities combined with non exhaustive use of natural resources, which is the main goal of contemporary nature use, ecological safety and nature protection. The recommendations were developed for the use of nature-protection and administrative bodies in decision making and any kind (land use, nature protection, ecological, etc) of studies.

Keywords: ecosystem, urban environment, territorial organization, nature use, biodiversity, local level, Transnistria.

Підходи до організації екомережі Придністер'я в умовах міського ландшафту

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Анотація. У статті, на основі, еколого-ландшафтного наукового підходу зроблена оцінка специфіки природокористування та умов функціонування (в тому числі відносно ступеня антропогенного впливу) на прикладі специфічного міського середовища Придністер'я – м. Ямпіль Вінницької області. Встановлено, що природні комплекси м. Ямпіль, як і Придністер'я загалом, зазнали значних змін, пов'язаних з тривалим у часі антропогенним впливом (будівництво промислових об'єктів і житла, забруднення повітря, води, ґрунтів, рослинності). Це призвело до загострення протиріч між мешканцями і навколишнім середовищем, що виражаються у виснаженні і деградації природної складової міських ландшафтів, погіршення умов проживання та зниження відтворювальної здатності середовища. Негативні зміни навколишнього міського середовища потребують розробки шляхів збалансованого розвитку території. Одним із шляхів узгодження виробничо-господарської діяльності з екологічними вимогами і обмеженнями є оптимізація співвідношення природних й антропогенних ландшафтів, яка забезпечується формуванням екомережі. У формуванні локальної екомережі м. Ямпіль вбачається найдієвіший на сьогодні механізм, який здатний забезпечити збереження і відтворення біотичного і ландшафтного різноманіття та сприятиме: дотриманню екологічної рівноваги; створенню

більш сприятливих умов для життя і розвитку місцевого населення, запобіганню безповоротній втраті частини гено-, ценофонду, екосистем і ландшафтів міста й околиць як частини Придністерської України; забезпеченню раціонального природокористування; розвитку ресурсної й рекреаційної бази для екотуризму, відпочинку та оздоровлення населення; ренатуралізації земельних угідь, що вилучаються із використання; посиленню узгодженості діяльності органів виконавчої влади, місцевого самоврядування, громадських екологічних і природоохоронних організацій у вирішенні проблем природокористування. Обраний масштаб локального рівня забезпечує достатню детальність досліджень міського середовища й оптимальну генералізацію результатів комплексної оцінки території. Логічне визначення місця локальної екомережі в екомережах вищого рівня, дає нам можливість стверджувати, що визначені нами її структурні елементи є однією з ключових їх територій, передусім, Дністровського екологічного коридору в Національній екомережі України. Тому збереження їх є завданням не лише для Ямполя, але й для усієї країни загалом.

Ключові слова: локальна екомережа, міський ландшафт, територіальна організація, природокористування, біорізноманіття, Придністер'я.

Introduction.

At the current stage of interaction between the nature and the community, especially acute is the problem of preservation of its dynamic balance. The importance of solving it is indicated by the general Assembly of the UN, the First Summit on issues of biodiversity with support of the global system of biodiversity for the period after 2020 (United Nations Summit on Biodiversity 30 September, 2020) and the report of a number of international organizations with the support of the UN (State of Climate Services 2020 Report, 2020). Having not decrying the threats of the global scale, we should note that the most intense and multi-faceted consensus of "co-working" between human and the environment is in large cities. No exception, but rather typical for the entire Ukraine, is the situation in cities of Vinnytsia Oblast (Hudzevych, 2004). In the urbanized landscape structure, which is developed on the basis of the interaction between the natural and anthropogenic subsystems, represented by structures, transportation-communication complexes, garden and park, ornamental and green and other components, the pattern of interrelations between human community and the environment is seen more notably and informatively than in any other place. Technogenic transformations of urban systems provide comfort and amenities to the inhabitants and at the same time serve hallmarks as shockingly disturbed environments. Excessively altered technogenic environment needs timely attention and action aimed at its rational organization (Hudzevych, 2012).

Researchers and practitioners (Voropaj, 1982; Tyutyunnik, 1991; Klieshch, Maksymenko, 2020) focusing on different aspects (economic, social, ethnic, nature-protection) of anthropogenic-technogenic environment point out imperfect pattern of urban development, which, in their opinion, directly affects the ecology and takes negatively impacts on the health of the population. Among other things, it comprises the use of physical-geographic and bioecologic approaches to define the territorial parameters of optimum condition of green zone of large cities, peculiarities of their functioning (Savytska, 2003), etc. One of the promising measures aimed at providing balanced development of urban territories is the ecological network (hereinafter – econetwork), which, unlike the already created and successful ongoing programs in Europe (EECONET, EMERALD (Emerald network), NATURA-2000, networks of biosphere and biogenic reserves) is legally supported in Ukraine (Vashchyshyn, 2014). Conceptually, this idea is related to the notions of stability, resistibility and capacity.

With the adoption of Law of Ukraine "On the General Scheme of Planning of the Territories of Ukraine" (07.02.02. № 3059-III) and Resolution of the Cabinet of Ministers of Ukraine "On Provision of Implementation of Law of Ukraine "On the General Scheme of Planning of the Territories of Ukraine" (29.08.02. № 1291), the development of ecosystem was included in the General Scheme of Planning Territories in Ukraine, which according to Article 1 of Law of Ukraine "On Planning and Development in Territories" (20.04.2000 № 1699-III) determines conceptual solutions of planning and use of the territories in the country. In turn, it was reflected in Law "On Protection of Lands" (19.06.03 № 962-IV). Development of ecosystem is included in the system of measures in the sphere of land protection (Article 22) and recognized as a measure of protecting lands of various categories (Article 50 and others).

Theoretical and practical provisions of the future ecosystem of Ukraine, taking into account the experience of development of national ecosystems in the European countries, are described in numerous publications (Hrynevetskyi, 2002; Rozbudova ekomerezhi Ukrainy, 1999; Shelyag-Sosonko Yu. R., Grodzinskij D. M., Romanenko, 2004 et al.). According to planners, basic elements of econetwork should be natural centers, buffer zones, ecological corridors, territories that are being restored, and territories of natural development. According to them also, the objects are defined as territories that are rich in biodiversity, or appropriate for combining centers of biodiversity in case of favorable development of environment-restoring functions of quasi-natural condition. This indicates that the strategic direction of implementation of the concept is solving two important tasks within the framework of protection of the natural wildlife (natural centers, buffer zones, ecocorridors) and taking care of the environment (restorative territories and territories of natural development) as the habitat for human life, focusing on high-quality condition of the environment to improve the health of the population. In their continuous integrity, they make up an eco-

network that functionally unites centers of diversity into an integral continental and water area system of various hierarchical levels: biosphere, all-European, National, Regional and Local.

It has to be noted that the opportunities of integrating urban systems into econetworks (locals, regional or other levels) are usually not taken into account, or considered at the level that is far from satisfactory, because the modern tendencies of the development of ecosystem use "green circles" of cities to travel around them. Therefore, to justify them, it is important to create local ecosystems within settlements at the lowest, i. e. local, level (Hudzevych, 2008). The implementation of this approach is relevant for the territory of Transnistria, particularly residential area of Yampil city, due to its location within the international Ukrainian-Moldovian Dniester (Dnistersky) ecocorridor.

The objectives of the study were Yampil city of Vinnytsia Oblast and its suburbs. The subject of the study was natural specifics of urban and suburban environment (object of nature-reserve fund; aquatic objects, wetlands, protected wet areas, protective bank belts; forests of various groups; recreational territories; other nature territories, including hayfields, meadows, pastures; areas with species of animals and plants of the Red Book of Ukraine; groups from the Green Book of Ukraine), as the main structural elements in the local ecosystem of Yampil.

The goal and purpose of the study were the geographic analysis of the constituents, development and prospects of development of the local ecosystem of the residential area as the basis for development of the regional ecosystem.

To achieve these goals we solved the following tasks:

1. Characterizing the peculiarities of natural geographic, biotic and landscape components of the territory of the study;

2. Determining the directions of nature use and the most notable anthropogenic changes and determining potentially appropriate lands to develop the local ecosystem of local residential area;

3. Proposing the scheme of ecosystem in Yampil based on geographical analysis of residential territory;

4. Identifying the significance of local ecosystem of Yampil in the regional and national models of ecosystem and modeling it on the example of territory of Yampil district and trans-border territory.

Materials and methods of study.

Study of the opportunity of creating the local network of Yampil was consistent with the Laws of Ukraine "On Ecological Network of Ukraine" (N 1864-IV of 24 June 2004) and "On National Programm of development of National Ecological Network of Ukraine for 2000–2015" (N 1989 of 21 September of 2000) and carried out taking into account the positions of Laws of Ukraine "On Protection of the Environment", "On Nature-Reserve Fund of Ukraine", "On Fauna", "On Flora", Land, Forest and Aquatic Codes of Ukraine, Decree of President of Ukraine of 23.05.2005 № 838/2005 "On measures for the further development of nature-protection in Ukraine", Decree of the Ministry of the Environment in Ukraine of 13.11.2009 № 604 "On approval of Methodic Recommendations for Development of Regional and Local Schemes of Econetwork". We took into account the other normative legal acts that are also related to creation, management and monitoring of the National Ecosystem of Ukraine: "On the basics of Urban Development"; "On land management"; "On local government in Ukraine"; Water and Land Codes of Ukraine, etc, and also strategic and program documents mentioned above.

To solve the complex issue of protection of landscape and biotic variety, Vinnytsia Oblast has enough experience of planning the use of land in its territory (Yatsentiuk, 2011; Hudzevych A., Liubchenko, Bronnikova, Hudzevich L., 2020; Hudzevich, Nikitchenko, Baiurko et al., 2020; Hudzevych A., Hudzevich L.,

Nikitchenko et al., 2021). Study of development of ecological network in Yampil is determined by a number of strategic and program regional documents, particularly "Regional Program Econetwork in Vinnytsia Oblast in 2004–2015", "Regional Program of Protection of the Environment and Rational Use of Nature Resources for 2013–2018", "Strategy of Balanced Regional Development in Vinnytsia Oblast for the period of 2020", "Complex program of creation and development of geoinformational system of management and urban development of the cadastre of Vinnytsia Oblast for 2016–2020", "Oblast Program of the Development of Forest and Hunting grounds in forests provided for regular use to Vinnytsia Oblast Specialized Forestry Vinoblagrolis, increase in forest coverage and greening of settlements in the Oblast and use of objects of global fauna in cultural-educational and pedagogical goals for the period of 2017–2021", "Regional Ecological Budget Program for 2019–2023", "Oblast Program of achieving optimum level of forest coverage in Vinnytsia Oblast for 2012–2025", "Program of development of tourism in Vinnytsia Oblast for 2021–2027".

Methodological basis of the conducted study was the International strategy of sustainable development, basic principles of which are defined in the Declaration of the International Conference of the UN on the environment and development in Rio Declaration in 1992. Furthermore, the work used methodologic approaches that were approved by the Resolutions of the European Union on preservation of wild birds (Council Directive 79/409/EEC on the conservation of wild birds) and preservation of

natural environments of wild fauna and flora (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora); described in the articles (Pashchenko, 2004; Samoilenko, Korohoda, 2013); recommendations (Formuvannia rehionalnykh skhem ekomerezhi, 2004), including the ones approved by the Ministry of Nature of Ukraine (Tymchasovi metodychni rekomendatsii shchodo rozroblennia skhem rehionalnoi ekomerezhi, 2006 p.; Pro zatverdzhennia metodychnykh rekomendatsii shchodo rozroblennia rehionalnykh ta mistsevykh skhem ekomerezhi, 2009 p.). The indicated methodological recommendations were suggested for the development of regional and local schemes of econetwork, they are recommendations prepared to provide help to territorial bodies of Ministry of Nature during projecting regional and local schemes of econetwork. Their fulfillment included combination of the following methods and approaches to the organization: analysis of archival and normative legal sources, materials of hydro-meteriological observation, transport organizations, forest- and land development, department of architecture; laboratory work focusing on herbarium and collected material; route field expedition surveys of residential areas and their surroundings (substantiated biogeographic study, landscape survey, ecopathological survey, monitoring transportation, etc); collection of corresponding field and material for the study, cartographic analysis, analysis of the obtained practical data with the purpose of theoretic generalization and development of the scheme of local econetwork.

Collection and analysis of the initial data on opportunity of developing a scheme of local econetwork of the residential area of Yampil were used in the 2017 survey (Vyhotovlennia proektu ekomerezhi m. Yampil, 2017).

Results and their analysis.

The surveyed territory was an interesting nature-territorial complex composed of urban settlement of a district significance – Yampil city and its suburbs, the administrative center of Yampil district of Vinnytsia Oblast since 1932. Since the new administrative territorial organization in Ukraine has been adopted and the Resolution of the Parliament of Ukraine "On creation and liquidation of districts" of July 19 2020 implemented, Yampil is subordinated to Mohyliv-Podillia district of Vinnytsia Oblast. The city founded in the second half of the XVI century borders with Moldova on the left bank of the Dniester river and lower current of its tributary – the Rusava river.

According to geobotanical zoning, the surveyed territory belongs to the European broad-leaved region, the Podillia Besarabian Province, Vinnytsia (Central Podillia) county, Right Bank-Dnipro forest-steppe province (Didukh, Sheliah-Sosonko, 2003). The preserved natural forest-steppe vegetation has been altered in the conditions of high anthropogenic activity and is now represented by modified forest, meadow and aquatic-wetland groups.

The results of field surveys indicate specificity of the vegetation in the local residential area, mainly composed of near-river and near-road alley greenings in the streets. In the areas around the stream, there grow thickets willow-oak and willow-acacia (grey willow *Salix cinerea L.*, goat willow *S. caprea L.*, sharp-leaf willow *S. acutifolia Willd.*; common oak *Quercus robur L.*; acacia yellow *Caragana arborescens Lam.* and acacia white *Robinia pseudoacacia L.*). In the floodplain part – true and waterlogged valley meadows and fragments of lowland herbaceous wetland. On the banks of the Dniester and its shallows, there are thickets of green algae (Entheromorpha and others), and also plots with higher vegetation developed by formations of rdest or water cabbage (rdest shiny *Potamogeton lucens L.* and rdest curly *P. Cricpus L.*), hornwort (*Ceratopyllum demersum L.*) and arrow head ordinary (*Sagittaria sagittifolia L.*).

Vegetation in the city and the suburbs is distinct by its complexity due to uneven moisture in the territory, microrelief and pattern of development, first of all residential and agricultural, by contrast to the Rusava right bank in the outskirts with hilly terrain. Not to mention other factors, just artisanal crafting from "stone" and private constructions in the XX – early XXI century were enough to significantly alter its nature. This led to emergence of depressions in the natural tree and herbaceous-shrub landscape of the Rusava hills, accompanied by disturbance of vegetation by irrational grazing (excessive). Capacity of the pastures was small, suitable for 0.2–0.3 individuals of cattle per one hectare according to optimum assessments. Small pastures within the slopes and floodplain and above-floodplain terraces of the Rusava and Dniester are too small for the population of goats (*Capra hircus L.*) that are grazed there.

A distinct trait of the vegetation in the city is that it is distributed in "islands" of tree-shrub vegetation which now occupy small areas and are often isolated one from another by structures and agricultural lands. They may be used as basis for developing park and aqua park recreational territories. The area of greenings of general use in the city equals 52.7 ha, which is around 9m^2 per one inhabitant, the norm being about 17m^2. The greenings include the local park, park squares, alleys, green zones, zones around the stream beds of the Rusava and Dniester, etc. Their development has begun in the late 1950s. In the village streets back then, dozens of thousands ornamental and fruit-bearing plants have been planted, which became the basis of the current green "dress" of Yampil.

We have to note the special significance of the green zone of the municipal institution of the central dis-

trict hospital (Yampil district medical center of emergency treatment – Pirohova st, 1). Among the typical leaved plants (common oak *Quercus robur L*., small-leaved linden *Tilia cordata* Mill., European ash *Fraxinus excelsior L*., sharp-leaved maple *Acer platanoides L*. and ash-leaved A. *negundo* L.) and coniferous species (European spruce Picea abies L. and silver spruce *P. pungens Engelm*., Scots pine *Pinus sylvestris* L.), there grow ornamental plants (white fir *Abies alba Mill*., juniper – Cossack juniper *Juniperus sabina L*., common juniper *J. Communis L*. and Irish juniper *J. Hibernica L*.) that serve as a shelter for representatives of fauna. Currently it is an example of optimization of species diversity, first of all, tree and shrub vegetation in the conditions of technogenic environment.

Recreational zone of the city was formed on the basis of the existing green plantations adjacent to the city from the side of Rusavy village, towards Halzhbiivka and the city park along the Dniester. The largest areas are located in the north (area around the railway station, streets Vynohradna, Nova Lisova, Horihova, Chereshneva, Lomonosova, Haidamatska) and northwest district (streets Kovpaka and Zhukova). Currently these territories are not used for their purpose and are considered potentially appropriate for constructing private homes. Only over the recent ten years, massive private construction and complexes of garden landlords have emerged in the territory of former vine gardens and fruit garden, in the district of streets Nova Yabluneva, Zhukova, Haidamatska. Furthermore, individual constructions, massively and chaotically in many cases, have recently been made in territories in different parts of the city.

Over the recent decades, the condition of greenings in Yampil has deteriorated, and the amount of green zones reduces. First of all, this is the result of construction of private homes and the infrastructure of the city and irrational measures for support and monitoring of greenings, which does not provide sufficient conditions for growth and development of plants. On the other hand, there is the climate change and therefore intensification of extreme weather phenomena (storms, droughts, glaciations, etc), as well as a nature-protection culture of the population. At the same time, negative tendencies are most notable in green zones around houses and roads, alleys and small garden squares.

According to the zoogeographical division (Shherbak, 1988), the territory of Yampil and its suburbs is within the Boreal European Siberian subregion, European West Siberian province, East European county, area of mixed, leaved forest and forest-steppe, Dnister-Dnipro area. Significant anthropogenic impact led to losses of many species, and a significant amount of them is identified to rare and is included in various nature-protection lists (Table).

Table. Rare species of animals

Class of animals	Species of animals	International list	Рівень загрози для тварин*
Insects	great capricorn beetle *Cerambyx cerdo L.*	IUCN Red List	VU
	red wood ant *Formica rufa L.*		LR 3
	emperor dragonfly *Anax imperator L.*	Red Book of Ukraine	RBU – VU
	European stag beetle *Lucanus cervus L.*		(RBM – EN, RBU – EN)
	mammoth wasp *Scolia maculata Druru*		RBM – EN, RBU – EN
	southern festoon *Zerinthia polyxena Denis*		RBM–CR, RBU – EN
	Jersey tiger *Callimorpha quadripunctaria Poda*		RBM–VU, RBU – EN
	Old World swallowtail *Papilio mahaon L.*		RBM–VU, RBU – EN
	European mantis *Mantis religiosa L*		RBM–VU
	giant peacock moth *Saturnia pyri* Schiffermuller		RBM – EN
Birds	corn crake *Crex crex L.* **	IUCN Red List	NT
	common pochard *Aythya ferina L.* **		NT
	ferruginous duck *Aythya nyroca Guldenstadt* ***		NT
	pygmy cormorant *Phalacrocorax pygmaeus Pallas©*		NT
	lesser white-fronted goose *Anser erythropus L.* ±		VU
	greater spotted eagle *Aquila clanga Pallas* ±		VU
	red-breasted goose *Branta ruficollis Pallas* ±		VU
	great bustard *Otis tarda L.*±		VU
	pallid harrier *Circus macrourus Gmelin*±		NT
	mute swan *Cygnus olor Gmelin* **	Red Book of Ukraine	RBM–VU
	European honey buzzard *Pernis apivorus L.* **		RBM – EN
	stock dove *Columba oenas L .***		RBM – EN
	whooper swan *Cygnus cygnus L.* ***		RBM–VU, RBU – EN
	common goldeneye *Bucephala clangula L.* ***		RBU – VU

Class of animals	Species of animals	International list	Рівень загрози для тварин*
Birds	short-eared owl *Asio flammeua Pontoppidan* ***	Red Book of Ukraine	RBM – EN
	little egret *Egretta garzetta L.*©		RBM–CR
	golden eagle *Aquila chraesaetos L.* ±		RBM–CR, RBU – VU
	black stork *Ciconia nigra L.* ±		RBM–CR, RBU – EN
	hen harrier *Circus cyaneus* L. ±		RBM–CR
	Montagu's harrier *C. pygargus L.* ±		RBM–CR
	osprey *Pandion haliaetus L.* ±		RBM–CR, RBU – VU
	saker falcon *Falco cherrug Gray* ±		RBM–CR, RBU – III
	white-tailed eagle *Haliaeetus albicilla L.* ±		NT
Mammals	pond bat *Myotis dasycneme Boie*	IUCN Red List	VU
	forest dormouse *Dryomys nitedula Pallas*		LR
	Eurasian otter *Lutra lutra Brisson*		NT
	European badger *Meles meles L.*	Red Book of Ukraine	RBM–VU, RBU – EN
	European pine marten *Martes martes L.*		
Reptiles and amphibians	European tree frog *Hyla arborea L.*	IUCN Red List	NT
	European pond turtle *Emys orbicularis L.*		LR
	garlic toad *Pelobates fuscus Laurenti*	Red Book of Ukraine	RBM–CR
	agile frog *Rana dalmatina Bonaparte*		RBU – VU
	smooth snake *Coronella austriaca Laurenti*		RBM – EN, RBU – EN
Fish	ide *Leuciscus idus L.*		VU
	common barbel *Barbus barbus L.*		RBM – EN, RBU – EN

*Categories of species under threat: CR – critically endangered, EN – endangered, VU – vulnerable, LR – lower risk, Nt (or LR / nt) – near threatened.
nesting;* overwintering; ©oversummering; ±migrating

Nature observations revealed that wildlife of the city and the outskirts is the reflection of climatic, vegetative and in particular environmental (land, water bodies) conditions. Therefore, the fauna of hydrobionts is represented by broadly distributed species of Gastropoda and Bivalvia mollusks *Theodoxus fluviatilis, Viviparus viviparus, Dreissena polymorph*a; larvae of insects range Trichoptera – of streams, Plecoptera – freckle, Ephemeroptera – one-day; Crustaceans, both lower (orders *Amphipoda, Isopoda, Copepoda* and others) and higher representatives of order *Decapod*a. Broadly distributed are Oligochaeta *Nais communis* and larvae of Chironomidae.

Bank and slope-ravine natural complexes with domination of stepped vegetative and shrub groups are habitats for rare and threatened species of vertebrates: amphibians (green frog *Pelophylax lessonae Fizinger*), reptiles (common European adder *Vipera berus L.*, snakes – ordinary *Natrix natrix L.* and water snake *N. tessellata Laurenti*). Near the islands and meanders of the Dniester where the current of water is weak, there occurs European marsh turtle (*Emys orbicularis L.*). Among agrocoenoses, there are mainly steppe areas, which are adjacent to the upper part of the forested slopes, inhabited by the lizard is agile (*Lacerta agilis L.*).

Diverse conditions of Yampil and its suburbs are optimum for nesting to a great number of birds. Most often, there are seen, both flying and at the nests, species of detachment Sparrows ((common starling *Sturnus vulgaris L.*, Eurasian tree sparrow *Passer montanus L.*, European goldfinch *Carduelis carduelis L.*, field skylark *Alauda arvensis L.*, Eurasian golden oriole *oriolus oriolus L.*). There is a quite large amount of representatives of families Raven (gray Raven *Corvus cornix L.*, common raven *Corvus corax L.*) and Picidae (great spotted woodpecker *Dendrocopus major L.*, lesser spotted woodpecker *Dendrocopus minor L.*). There were seen nesting storks Ciconia ciconia L., and also some species of diurnal birds of prey of Falconiformes order and representatives of nocturnal birds of prey of Strigiformes order (long-eared owl Asio otus L. and little owl Athene noctua Skopoli.

West of Yampil, in the valley of the Dniester, there are wetlands (5,394.28 ha) that are protected by the Ramsar Convention. Many birds use these areas to nest, overwinter or stay before the flight for wintering, particularly mallard *Anas platyrhynchos L.*, common coot *Fulica atra L.*, common goldeneye *Bucephala clangula*, mute swan *Cygnus olor*, whooper swan *Cygnus cygnus*, *Mergus* – common merganser *Mergus merganser L.*, red-breasted merganser *M. serrator L.* and smew *M. albellus L.*, tufted duck *Aythya fuligula L.*, Eurasian wigeon *Anas penelope L.*, greylag goose *Anser anser L*, *Ardea* – grey heron *Ardea cinerea L.* and great egret *A. Alba L.* Among those birds, there are lesser white-fronted goose *Anser erythropus L.*, ferruginous duck *Aythya nyroca Gueldenstadt*, white-tailed eagle *Haliaeetus albicilla Pallas*, greater spotted eagle *Aquila clanga Pallas*, great bustard *Otis tarda L.*, included in the Appendix I of the Convention of Protection of Migrating Species of Animals, and al-

most all of them are in the list of species strictly protected by the Berne Convention (for example, little grebe *Tachybaptus ruficollis Pallas*, little egret *Egretta garzetta*, white stork *Ciconia ciconia*, smew *Mergus albellus L.*, common sandpiper *Actitis hypoleucos L.*). Some rare species regularly overwinter in the area: common merganser *Mergus merganser L.* (RBM – DD), red-breasted merganser *Mergus serrator L.* (RBU – EN) merlin Falco columbarius L. (RBM – DD) (Matviichuk, Pirkhal, Reminnyi, 2015).

In the bend of the Dniester River, the rocks of the Cretaceous marlstones (near the cave complex of Oksanivka village) are the nesting places of the colonies of wild ducks and swans. In some caves and natural recesses of the canyon, wild birds of Accipitridae family are nesting. There also occur swallows, hoopoes, crows, eagle-owls.

Birds of wetlands concentrate mostly in the zones of shallow water and places where the Dniester flows slowly: the extension of the river stream bed, area of its bends, recreation zones near the alluviums, formed by the Murafa and Rusava tributaries. There are more of such places in the western suburban part of the city on the left bank of the river. Nonetheless, the diving ducks and Old World cormorants are not that attracted to such plots. Birds gather to rest on the sandspits, the shallow water areas, which become exposed from time to time, piles of rocks, trunks of fallen trees in the areas with any current speed. In winter, the birds are concentrated in non-freezing shallow water areas of the river, and diving species in deep water areas where they feed. Therefore, they may occur right near the city, which is rarer in other seasons.

Indirect signs such as traces to burrows indicate presence of such mammals as European hare (*Lepus europaeus Pallas*), red fox (*Vulpes vulpes L.*), European badger (*Meles meles L.*), least weasel (*Mustela nivalis L.*). Rarely there occur reports of wild boar (*Sus scrofa L.*), roe deer (*Capreolus capreolus L.*), muskrat (*Ondatra zibethicus L.*) and Eurasian otter (*Lutra lutra Brisson*).

Biodiversity of ichthyofauna of the Dniester and the areas adjacent to Yampil is characterized by the effect of artificially created dams of the Dubăsari Dam and Novodnistrovsk Hydroelectric Power Station which completely exclude the opportunities of migration for species of fish (catadromous, straddling): representatives of sturgeons *Acipenseridae*, *Clupeidae*, freshwater eels *Anguillidae*. Aquatic animals are especially vulnerable, both invertebrates and vertebrates, in the periods of reproduction, spawning, when they need stable abiotic factors (temperature, pH, salt content, speed and level of water, presence of suspensions in the form of slit-sandy components, etc). Unfortunately, the period of reproduction of aquatic animals coincides with the spring high water, when the dams cause intense water discharges, thereby taking an extremely negative effect on the following course of reproduction and preservation of species.

At the same time, in the Dniester and the mouth of the Rusava, there often occur common roach (*Rutilus rutilus L.*), common bream (*Abramis brama L.*), common bleak (*Alburnus alburnus L.*), common carp (*Cyprinus carpio L.*), *Prussian carp* (*Carassius gibelio Bloch*), European perch (*Perca fluviatilis L.)*, pike (*Esox lucius L.*), common rudd (*Scardinius erythrophthalmus L.*), common chub (*Squalius cephalus L.)*, gudgeon (*Gobio gobio L.*) and others.

In the landscape aspect, the area is characteristic of floodplain and above floodplain-terrace loess plains. Their natural appearance had been lost, as well as attractiveness and esthetic value. The destructive factors are the use of the subsoil and extraction of construction materials by open method both by individuals and companies, construction of roads, high voltage power lines, pipelines and structures (Fig. 1). There are all kinds of chemical and physical pollutions: wastes of

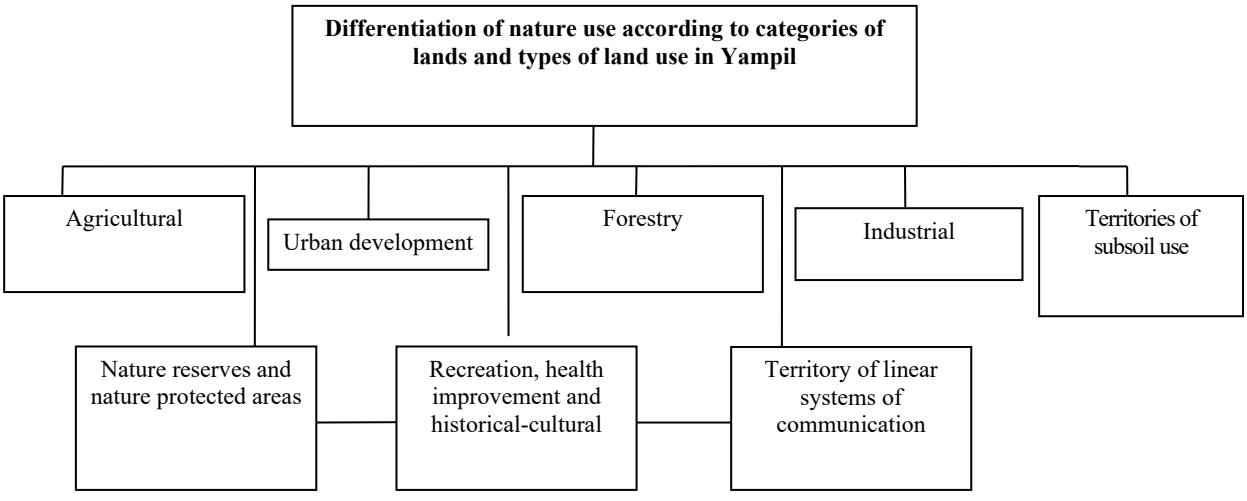

Fig. 1. Directions of nature use in Yampil

industrial and agricultural activities, traces of fertilizers and pesticides.

Most notable changes in anthropogenic load are as follows:

- Changes in landscapes and loss of attractiveness of notable places (for example changes in the lower mouth part of the Rusava river and vanishing of the natural tributary near the current city park).

- Decrease in the esthetic attractiveness of herbaceous-shrub slope areas of the northern outskirts of the city due to loss of natural appearance as a result of irrational nature use (private mining, massive construction, etc);

- Decrease in the esthetic attractiveness of slope and floodplain and above floodplain herbaceous groups due to decrease in bright flowering plants and insects (butterflies) and impact of degradation;

- Obvious changes in the stream bed of the Rusava, decrease in the thickets around the river.

At the same time, the threats increase the significance of the protection of natural complexes of the region of study, the need in which is indicated by:

• significant decrease in bioproductivity of forest and pasture ecosystems;

• changes in the opportunities for growing some species and many varieties of agricultural crops;

• reduction of resistibility of the areas with trees (sessile oak Quercus petraea, ash, hornbeam, and others), especially those that are young and those that originated from alien species (black locust, Scots pine and *Pinus nigra*);

• optimization of the structure of natural ecosystems and unfavorable changes in the ratio of open and vegetation-covered areas, decrease in water protection function of shrubs and trees;

• intensification of displacement of aboriginal species by aggressive alien species such as *Ailanthus*, box elder *Acer negundo* and emergence of plant species which are new to the territory, mostly weed aggressive invasive species;

• likely disappearance of some large birds of prey, birds of open areas and species that live in the southern borders of the range;

An important condition is that vulnerable environment is poorly protected by the traditions and laws.

Decrease, prevention and liquidation of negative impact of agricultural and other activities of Yampil on the environment, as well as preservation of natural resources, genetic fund of wildlife may be promoted by development of the city`s econetwork. First of all, it manifests in changes in the structure of land fund of the city through identification (based on substantiation of ecological safety and economical expedience) of some agricultural lands to categories that require special protection with restoration of the diversity they are characterized by such an approach correlates with the modern views of researchers, according to whom, the econetwork should be developed on the basis of optimization and re-naturalization (naturalization) of anthropogenically modified geosystems, first of all landscapes (Buček, 2013; Moyzeová M., Kenderessy P., 2015] where biotic component is considered a stabilizing factor providing ecologic balance.

As of 01.09 2020, the general area of lands of the city council accounted for 2,546. 0 ha. Quite a significant part is occupied by lands of agricultural use – 1,698.85 ha (63.92 % of the total area).

According to our estimations, the promising econetwork of Yampil may include:

• forest and other forest-covered areas – 279.0 ha;
• degraded lands – 8.2 ha;
• low-productive arable lands –249.55 ha;
• multi-years plantations (gardens) – 152.25 ha;
• pastures – 13.4 ha;
• greeneries of general use – 93.1 ha;
• gullies and steep slopes – 4.75 ha;
• areas of aquatic fund – 86.5995 ha;
• lands used for recreation and other open areas (including cemeteries) –11.2783 ha;

To create a substantial buffer zone, the lands of the econetwork should include arable lands of the store – 35.3 ha and lands of the reserve – 102 ha. Thus, the overall area of the lands included in the network by the city council accounts for 1,035.43 ha, i. e. 40.67 % of its overall area (2546.0 ha).

Traditional methods of forming elements of the ecosystem are based on unification of already existing objects of the nature reserve fund (Shelyag-Sosonko, Grodzinskij, Romanenko, 2004) that usually are the basis for the biocenters at any level of National Econetwork. In the conditions of functioning nature-reserve objects, their contours automatically result in configuration of key territories of the econetwork. Unfortunately, within Yampil, there is only one nature protection area – the Yampil Layers – geological nature relic of local significance (Fig. 2), the area of which equals 0.05 ha. The projected spatial-functional structure of the local Econetwork of Yampil comprises natural (location of key territories, hydrographic network of the city, presence of forest and herbaceous and shrub areas, etc) and social conditions (residential area and industrial constructions, etc). Hierarchic structure of Yampil econetwork (Fig. 2) consists of 4 key territories (all of local significance), 36 connective territories (including 1 of International, 2 – National, 1 – Regional and 32 Local significances). The key and connective territories of local econetwork of Yampil are compartmentalized based on the adopted criteria of selection and are indicated on the map (Fig. 2).

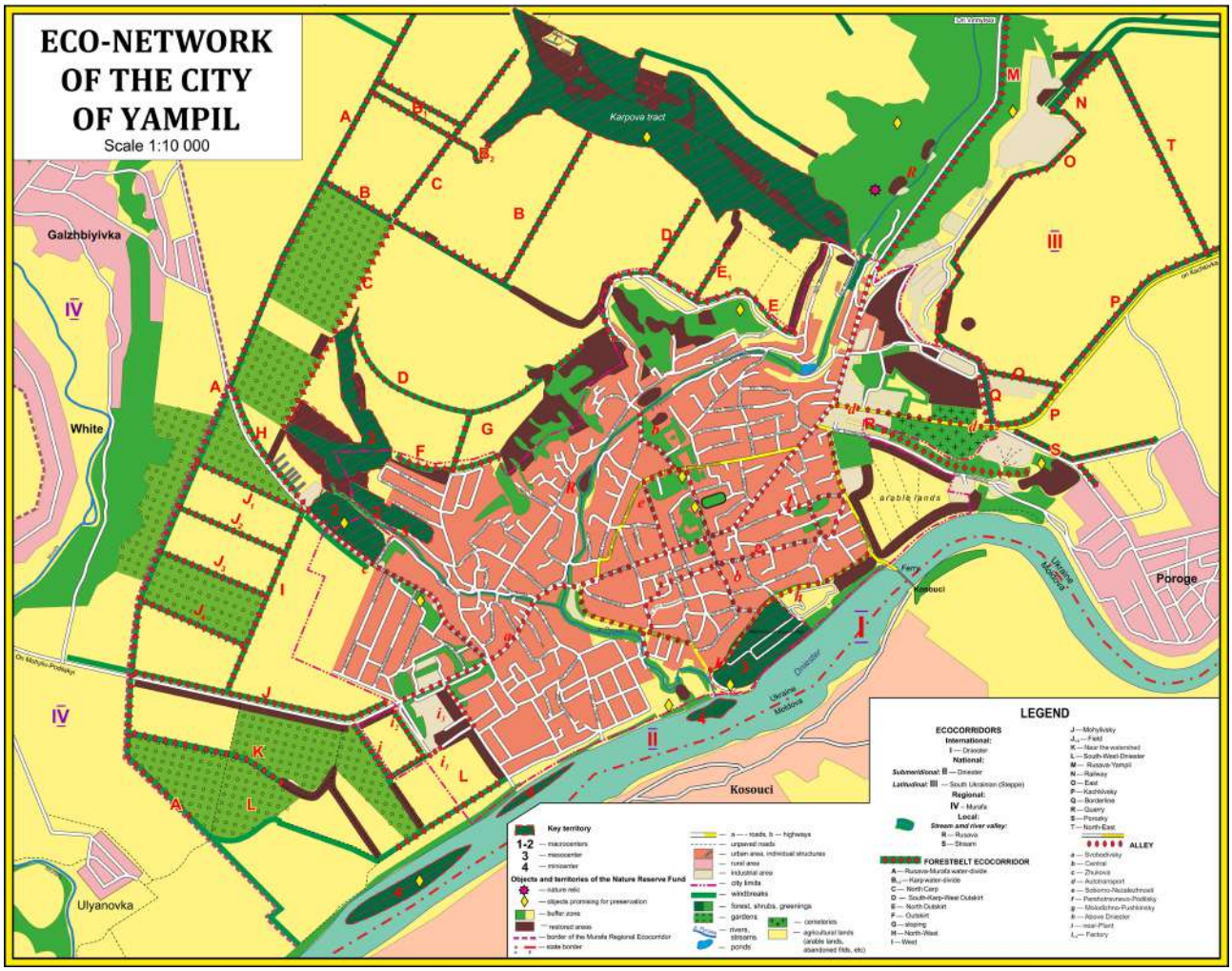

Fig. 2. Project of econetwork of Yampil

The map of promising econetwork has been developed first of all based on visual observations and expedition surveys of the territories, by indicating the key, buffer and restoring territories on the maps. To develop it, we used topographic maps of the area, aerial photographs, schematic maps of soils, localities of rare species and plant groups; maps of various scales (general geographic, tectonic and geological structure, climate). We employed fund materials of services of the city council, geobotanical materials of forest management, state service of the nature protection in Vinnytsia Oblast and other available materials.

Using the qualitative background method, we indicated: the main elements (key, connective, buffer, restoring territories) of the local econetwork; natural and anthropogenized territories and objects, particularly: individual categories of lands (arable lands, fallow lands; lands with constructions, city and village development, lands of industrial objects); windbreaks; types of vegetation (forest, turf-shrub); hydronetwork (river valleys, ponds), industrial and transport infrastructure (roads, highways and soil and field roads), etc.

- Furthermore, the integrated map indicates nature-protected objects and promising reserve territories, including linear: street network; city borders; State border and the border of the Murafa ecocorridor of Regional Value.

- For better visualization, the key elements of the local econetwork are hatched.

- The structural specifics of the projected local econetwork should include:

- its relative easiness due to significant development and constructions in the territories;

- presence of four key territories (2 macrocenters, 1 mesocenter and 1 mini center) that represent landscape and biotic diversity of the studied territory;

- presence of distinct ecocorridors – the core Rusava and supporting Dniester ecorridors. The latter is a contact element of the local econetwork of the city and regional, National and trans-national econetworks;

- Proximity to the Murafa ecocorridor of the Regional Level;

- Distinct expression of "protection" of the key territory of the Dniester Islands and the northwest part the Karpova Tract and slight expression of this aspect

around the natural center the Northern Outskirts and the Rusava ecocorridor in the most part of its strike;

- Presence of eleven elements of econetwork within the territories and objects promising for protection which would increase the effectiveness of the econetwork.

No doubt, the Yampil local econetwork is a component of the ecosystems of a higher level – International, National and Regional. First of all, it requires correlation with the regional one, development of which is currently still underway. Nonetheless, some of its main structural elements are already determined by the Decision of Session 10 of Vinnytsia Oblast Administration VI convocation № 282 from Febrary 14 2012 when there was adopted the Regional Scheme of the Oblast Econetwork and which enable the corresponding allocation. Therefore, in the west, the lands of Yampil directly border with the basin of the Murafa river, the valley of which is a regional ecological corridor that is connected with the sub-meridian Dniester ecocorridor in the north and forms one of the three National nature centers of Vinnytsia Oblast – the Dniester-Murafa. In the north, it connects to the regional landscape park Murafa. The latter, having the area of 3,452.7 ha, was created in 2008 in the territories of Chernivetska and Mohyliv-Podillia districts of Vinnytsia Oblast. It comprises the alley of the Murafa river from the urban settlement Chernivtsi to Sloboda-Bushanska village, the lower part of the valley of the Lozova river, the Vazlui river and the Haidamatsky gully in the Bushanka river.

The Rusava river is an interactive element in the development of regional econetwork and at the same time, is one of the main ecological corridors in the formation of local econetwork.

The territory of Yampil local econetwork crosses the Dniester meridian corridor of International (All-European) value, the main pathway of seasonal migrations of the fauna through Ukraine and Steppe National latitudinal corridor. On the Dniester River, the Dniester Regional Landscape Park borders with the Moldova Unguri-Holosnita wetlands of International significance (Ramsar site).

Conclusions.

The development of the project of the local scheme of the econetwork for Yampill is a logical continuation of the efforts on creating the regional econetwork of Vinnytsia Oblast. It is a reflection of one of the three links of interrelated, subsequent in execution algorhythimic 3-stage scheme of development of complete network where stage I is the development of the project of the initial regional scheme of econetwork, stage II – development of projects of local schemes of econetworks and stage III – development of the regional scheme.

Taking into account that the Yampil Local Econetwork is a component of econetworks of higher levels – International, National and Regional, it first of all requires correlation with the regional one, development of which is currently still underway. The correlation of the scheme with the project of National Econetwork of Moldova remains the important issue, because the territory of Yampil local econetwork is located at the place where it crosses the Dniester meridian corridor of international (All-European) significance, the main pathway of migration of fauna through Ukraine. Constant monitoring is required for the processes of transformation of the structures of lands which are indicated in the General Plan of the city, first of all, significant increase in the area of lands of the settlement with constructions. Any planned improvements should be substantiated and pose no threats to biotic and landscape diversities, both in Yampil specifically and Transnistria in general.

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Complex Assessment and Forecasting of Chemical Pollution of Small Rivers by Economic and Mathematical Modelling Methods

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Abstract. The purpose of this work is to determine the hydrochemical parameters of the water of the river Seret and the features of the accumulation of heavy metals by bivalve molluscs *Unio pictorum L.* to predict the chemical contamination of the reservoir in the near future. Water samples for the study were taken in spring (April) and summer (July) from the Seret River at two points: above and below Ternopil. It is established that the chemical composition of the water of the river Seret is formed under the influence of a number of factors, but seasonal and anthropogenic factors play a dominant role. In the spring season, a number of hydrochemical indicators (pH, water hardness, concentration of NO_2^-, NH_4^+, Cl^- ions and metals) have lower values than in the summer. In addition, there is an increase in the amount of organic matter, ammonium cations, nitrite ions, chloride ions, phosphate ions and a decrease in oxygen concentration below Ternopil, especially in the summer season. This is evidence that the Seret River is under significant anthropogenic impact. An increase in the concentration of metals (Mn, Cu and Pb) in summer below Ternopil was revealed, which may be due to the discharge of insufficiently treated wastewater. The series of metal concentrations in the water of the Seret River looks as follows Mn → Zn → Pb → Cd → Cu, and the series of accumulation of metals in the tissues of molluscs *Unio pictorum* L. has the form Zn → Mn → Cu → Pb → Cd. On the basis of bioaccumulation coefficients of heavy metals by molluscs, a prediction of the situation on their content in water for the short term based on the theory of Markov chains was made. This theory allows us to make forecasts of a factor, taking into account the possibility of accidental influences on the environment, and to investigate the highest probability of finding a factor in a certain numerical parameter. The possibility of using economic and mathematical modelling tools and statistical methods based on correlation-regression analysis using modern Matlab information systems to identify correlations between chemical indicators of water quality and biological molluscs for modelling the environmental situation of the river Seret and assessing the contribution of the studied indicators in pollution of small rivers is shown.

Keywords: small rivers, heavy metals, bivalve mollusc, prediction of bioaccumulation coefficients of metals, economic and mathematical modelling.

Комплексна оцінка та прогнози хімічного забруднення малих річок методами економіко-математичного моделювання

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Анотація. Малі річки є початковою ланкою річкової мережі, і всі зміни у їх режимі, безперечно, позначаються на всьому гідрографічному ланцюзі. Тому актуальною проблемою сучасної гідрохімії та гідроекології є оцінка антропогенного навантаження на малі річки України. Метою роботи є визначити гідрохімічні показники води річки Серет та особливості акумуляції важких металів двостулковими молюсками *Unio pictorum* L. для прогнозування хімічного забруднення водойми на найближчу перспективу. Проаналізовано такі гідрохімічні показники: pH, кисень, загальна твердість води, нітрати, нітрити, катіони амонію, фосфати, хлориди, перманганатна окислюваність. Зразки води для дослідження відбирали весною (квітень) та літом (липень) із р. Серет у двох точках: вище і нижче м. Тернопіль, що дало можливість оцінити рівень антропогенного тиску та хімічного забруднення річки. У результаті комплексного гідроекологічного дослідження гідрохімічних показників проведено оцінку якості води річки Серет. Визначено концентрації марганцю, цинку, міді, плюмбуму і кадмію у водоймі та особливості їх накопичення двостулковими молюсками *Unio pictorum* L. Розраховано коефіцієнти біоакумуляції, які відображають відношення вмісту металу в організмі гідробіонта до вмісту його в навколишньому середовищі. Виявлено позитивну кореляцію між вмістом металів в печінці двостулкових молюсків та їх вмістом у воді. На основі коефіцієнтів біоакумуляції важких металів молюсками здійснено прогноз

ситуації по їх вмісту у воді на найближчу перспективу на базі теорії ланцюгів Маркова. Дана теорія дозволяє здійснювати прогнози чинника, враховуючи можливість випадкових впливів на середовище, та досліджує найбільшу ймовірність перебування чинника в певному числовому параметрі. Показано можливість застосування інструментарію економіко-математичного моделювання та статистичних методів на основі кореляційно-регресійного аналізу з використанням сучасних інформаційних систем типу Matlab для виявлення кореляційних зв'язків між хімічних показників якості води та біологічними показниками молюсків для моделювання екологічної ситуації р. Серет та оцінки внеску досліджуваних показників у забруднення малих річок.

Ключові слова: малі річки, важкі метали, молюски, прогнозування коефіцієнтів біоакумуляції металів, економіко-математичне моделювання.

Introduction.

Small rivers contain the bulk of Ukraine's freshwater reserves and play a huge role in the life of the population. According to experts, they form for 60 % of Ukraine's total water resources. 60 % of water resources of these rivers are concentrated in Polissia and Forest-steppe, about 25 % in Carpathians and about 12 % in Steppe (Arsan et al, 2006; Lashko, 2008).

Small rivers are the initial link of the river network, and any changes in their regime are undoubtedly reflected throughout the hydrographic chain. Therefore, the current problem of modern hydrochemistry and hydroecology is the assessment of anthropogenic load on small rivers of Ukraine (Loucks, 2017).

The main sources of pollution of reservoirs are industrial and household effluents, with which pesticides, heavy metal ions, etc. are getting into the reservoirs in increasing quantities (Arsan et al, 2006). Heavy metals belong to the class of conservative contaminants that are not used or decomposed during migration on trophic chains, have mutagenic and toxic effect, significantly reduce the intensity of biochemical processes in aquatic organisms (Abubakar et al, 2015; Malik et al, 2014; Manoj et al, 2012; Mur, 1987). Some abiotic factors such as changes in acidity, mineralization or water temperature are not less dangerous for the life of hydrobionts (Altenburger, R. et al. 2019; Yan, 2015).

Bivalve molluscs are one of the functional units of aquatic ecosystems through which trace elements flow. By the way of nutrition they are referred to as filter feeders. This helps the molluscs to purify water and accumulate various metals, including toxic ones, in soft tissues. The ability of certain species of bivalve molluscs to accumulate high concentrations of metals, availability, prevalence and low migration activity, allows the use the bivalve molluscs as bioindicator organisms (Chapman,1996; Novikov et al, 1990).

In view of the above, the purpose of this work is to determine the hydrochemical parameters of the river Seret water and the features of the accumulation of heavy metals with bivalve molluscs *Unio pictorum L.* to predict the chemical contamination of the reservoir in the near future.

Material and methods of the research.

Water samples for the study were collected in spring (April) and summer (July) 2015 from the Seret River at two points: above and below Ternopil city, which gives an opportunity to estimate the level of anthropogenic pressure and chemical pollution of the river. After sampling, water samples were recorded and transported to the laboratory for testing. The determination of hydrochemical parameters and the content of heavy metals were carried out by conventional methods (Arsan et al, 2006; Novikov et al, 1990).

For studies of metal content and enzyme activity in bivalve mollusc *Unio pictorum* L., we selected the liver and used standard techniques (Nasrabadi, 2015).

Statistical processing of the obtained data was performed using the "Microsoft Excel" package. Prediction of metal content for the near future was performed using a prediction technique based on Markov chain theory and modern information systems such as Matlab (Prystavka, 2017; Rohatynskyi, 2017).

Results and their analysis. 1. Analysis of general chemical indicators of water quality.

We analyzed some of the hydrochemical parameters of the Seret River waters above and below Ternopil city (table 1).

The pH index of the water was the lowest in spring above Ternopil (pH 6.8) and the highest in summer below Ternopil (pH 7.5). According to this indicator, river water can be attributed to neutral waters characterized by the presence of $Ca(HCO_3)_2$, $Mg(HCO_3)_2$.

The oxygen concentrations in the water of the River Seret ranged from 4.67 to 7.95 mg / l. The highest oxygen content was observed in the spring above Ternopil city, and the lowest in the formation below Ternopil city. Probably lower oxygen content in summer is associated with higher organic matter content, as evidenced by the permanganate index.

Water hardness is a property of natural waters that depends on the presence of dissolved salts of calcium and magnesium in it. The highest indicator of total water hardness in the Seret River was observed in summer below Ternopil, the lowest value of total hardness was observed in spring in the area above the city. The water of the Seret River can be attributed to waters of medium hardness.

The maximal concentration of nitrates in water was noted in the spring below Ternopil city. Obviously, NO_3 ions get into surface water as a result of the washing of mineral fertilizers during spring floods. It also should be noted that their inflow with urban wastewater, as evidenced by the increase in their concentration in the stream below Ternopil city.

Table 1. Separate hydrochemical parameters of the river Seret (M ± m, n = 4)

Indicators	Spring		Summer	
	Above Ternopil	Below Ternopil	Above Ternopil	Below Ternopil
pH index	6.80±0.15	7.35±0.10	7.45±0.20	7.50±0.15
Oxygen, mg O_2/dm^3	7.95±0.06	5.73±0.19	6.86±0.22	4.67±0.37
Total hardness of water, *mmol/l*	5.16±0.05	5.58±0.07	6.52±0.04	7.10±0.02
Nitrates (NO_3^-), *mg/l*	6.63±0.12	8.82±0.14	2.63±0.42	5.94±0.15
Nitrites (NO_2^-), *mg/l*	0.03±0.01	0.05±0.02	0.07±0.05	0.14±0.02
Ammonium cations (NH_4^+), *mg/l*	0.09±0.01	0.72±0.03	0.23±0.03	0.92±0.03
Phosphates (PO_4^{3-}), *umol/l*	0.07±0.02	0.20±0.02	0.04±0.01	0.25±0.03
Chlorides (Cl^-), *mg/l*	11.40±0.90	16.55±1.20	28.50±1.60	35.40±0.90
Permanganate oxidation, *mmolO/l*	5.14±0.07	5.42±0.08	5.58±0.07	8.12±0.09

The highest concentration of nitrite ions (0.14 mg / l) was observed below Ternopil in summer. This indicates that the river water is contaminated with wastewater regularly, often municipal wastewater that is not treated sufficiently.

Concentrations of NH_4^+ ions in the water of the River Seret range from 0.09 to 0.92 mg / dm^3. It should be noted that in the summer season the concentration of ammonium nitrogen is higher. The study of the content of phosphate ions shows an increase in their quantity below Ternopil and emphasizes the fact of the phosphates supply with wastewater in Ternopil city.

Concentrations of chloride ions range from 11.4 to 35.4 mg / dm^3. The tendency of increasing Cl – ions in the summer season is noted. In addition, the increase of the chloride ion fraction from 28.50 mg / dm^3 in the Seret River above Ternopil city to 35.4 mg / dm^3 in the Seret River – below Ternopil city is clearly visible.

2. Gross metal content in the water of the Seret River.

We have determined the gross concentrations of manganese, zinc, copper, plumbum and cadmium in the water of the Seret River above and below Ternopil (table 2).

Table 2. Total metal content in the Seret River water (M±m, n=5)

Metal	Spring		Summer	
	Above Ternopil	Below Ternopil	Above Ternopil	Below Ternopil
Zn	0.015±0.006	0.019±0.004	0.020±0.005	0.018±0.002
Mn	0.019±0.003	0.025±0.003	0.023±0.003	0.045±0.003
Cu	0.0008±0.0002	0.0009±0.0002	0.0006±0.002	0.0015±0.001
Pb	0.009±0.002	0.011±0.003	0.009±0.002	0.015±0.002
Cd	0.003±0.001	0.007±0.002	0.007±0.001	0.009±0.002

The level of zinc in water varies within a fairly narrow water range from 0.025 to 0.030 mg / dm^3. However, there may be a risk of accumulation of metal by hydrobionts and their chronic poisoning. Its toxicity is caused by antagonism with other heavy metals.

The concentration of manganese in the water of the river Seret varied from 0.019 to 0.045 mg / dm^3. There was a sharp increase in Mn content in the summer below Ternopil. The high content of manganese can be caused by the relatively low oxygen content during this period, which causes the inflow of metal from the

bottom sediments due to recovery (under conditions of oxygen deficiency), the good water solubility of its compounds, their low complexing ability and high migration capacity.

Manganese can pose a significant danger to hydrobionts due to the high mobility of the metal and the relatively high level of "free" ions that have the greatest toxicity.

There is a noticeable increase in the concentration of cuprum in the Seret River basin below Ternopil city during the summer season. Lead content in river water was in the range 0.009–0.015 mg / dm3. The maximal concentration of metal was observed in the summer season in the formation below the city and exceeded the background level by 1.5 times.

The cadmium concentration in the river Seret varied from 0.003 to 0.009 mg / dm^3. The minimal concentration of metal was observed in the spring season above Ternopil, and the maximal – in the summer in the river bed below the city.

In general, the series of metals distribution in the water of the Seret River is as follows Mn → Zn → Pb → Cd → Cu.

3. Features of metal accumulation by mollusks.

Bivalve mollusks are one of the functional parts of aquatic ecosystems through which the flows of microelements pass. According to the method of feeding they are referred to as filters. The mollusk 20–30 mm long passes 1.5–2.0 l of water a day. As a result, mollusks help to purify water and accumulate various metals in soft tissues, including toxic ones (Anawar, 2020).

The penetration of heavy metal ions into the body of aquatic animals and their accumulation depend on many external and internal factors. The molecular mechanisms of this process are still understood poorly. It is only known that in general the penetration of heavy metal ions into the body of aquatic organisms includes the following stages: binding to the mucous epithelium; transport across the apical membrane; penetration of metal through the basolateral membrane, at the level of which the regulation of flow takes place; transportation of metals by blood flow to all parts of the body. The liver, being one of the main organs involved in important metabolic processes, and in which there is a detoxification of a number of harmful substances, is characterized by a high ability to accumulate metals (Neiko, 2003; Khochachka, 2002).

The accumulating ability of hydrobionts is usually expressed by bioaccumulation coefficient (K), which reflect the ratio of metal content in the body to its content in the environment (water, soil):

$$K = Cm / Cw, \quad (1)$$

where Cm and Cw are the metal concentrations in the mollusc tissues (mg/kg) and the metal concentrations in the water, mg/dm^3. The obtained data made it possible to calculate the bioaccumulation rates of heavy metals by shellfish with respect to water (Nasrabadi, 2015).

Data on the accumulation of individual metals in the liver of bivalve mollusk Unio pictorum L. caught in the River Seret are presented in the table 3.

Table 3. The content of metals in the liver of the bivalve mollusks *Unio pictorum* L. (mg / kg of wet tissue)

Metal	Spring		Summer	
	Above Ternopil	Below Ternopil	Above Ternopil	Below Ternopil
Zn	31.5	32.6	33.7	29.9
Mn	11.5	12.6	13.7	31.9
Cu	1.5	1.2	1.7	3.4
Pb	0.5	0.6	0.7	1.4
Cd	0.55	0.7	0.75	0.8

The analysis of the results indicates a rather high level of zinc accumulation (29.9–33.7 mg / kg) in the liver of molluscs and the absence of seasonal features of the accumulation of this metal in the liver of molluscs. The manganese content was slightly lower compared to zinc. However, a positive correlation should be noted between the concentration of manganese in water and the tissues of *Unio pictorum* L. Thus, the maximal concentrations of Mn in both water and in the liver of mollusks were observed in samples taken from the Seret River below Ternopil.

Our data suggest that increasing the concentration of copper ions in water leads to an increase in their content in the liver of bivalve molluscs. Thus, the maximal amount of metal was accumulated by molluscs caught in the Seret River in the summer below Ternopil. It is obvious that there is a positive correlation between the metal content in water and in the liver of molluscs, which is confirmed by the bioaccumulation coefficient.

The study found a relatively small amount of accumulated lead by the mollusc liver. The metal content ranges from 0.5 to 1.4 mg / kg of wet tissue. It should

be noted, that the increase in the amount of accumulated metal in the summer in molluscs selected below Ternopil, which is confirmed by the coefficient of bioaccumulation (k = 93.3). Obviously, this is due to the inflow of insufficiently treated wastewater into the river.

The analysis of the obtained results showed that the amount of cadmium in the liver of *Unio pictorum* L. tends to increase slightly in molluscs that were caught below Ternopil. The metal content in the liver of aquatic organisms varied in the range of 0.55–0.80 mg / kg, and the bioaccumulation coefficient ranged from 89 to 183.

In general, the series of metal accumulation in the tissues of the molluscs of *Unio pictorum* L. has the following form Zn → Mn → Cu → Pb → Cd. The accumulation of heavy metal ions by molluscs is an active and regulated process, which depends on both the physicochemical features of the environment and the physiological and biochemical activity of the body of the hydrobionts.

The coefficients of heavy metal bioaccumulation are have the following form Zn> Cu> Mn> Cd> Pb (table 4).

Table 4. Metal bioaccumulation coefficients by bivalve mollusc *Unio pictorum* L.

Metal	Spring		Summer	
	Above Ternopil	Below Ternopil	Above Ternopil	Below Ternopil
Zn	2100	1716	1685	1661
Mn	605	504	595	709
Cu	1875	1333	1833	2266
Pb	56	59	78	93
Cd	183	100	107	89

Consequently, molluscs accumulate significant amounts of metals, and bioaccumulation factors can indicate both the contamination of the environment with these metals and their accessibility to hydrobionts. In general, a positive correlation can be observed between the content of metals in the liver of bivalve molluscs and their content in water.

4. Prediction of bioaccumulation of metals by economic and mathematical modelling methods.

On the basis of the input data presented in table 3, we model the ecological situation based on the theory of Markov chains for the short term. The calculations will be made using Matlab.

Incoming data:

Metal	Zn	Mn	Cu	Pb	Cd
Spring/above Ternopil city	2100	605	1875	56	183

Construct a matrix of metal bioaccumulation coefficients in Matlab.

```
>>A = [2100 605 1875 56 183]
A =
    2100    605    1875    56    183
```

Find the sum of the metal bioaccumulation coefficients: 4819

```
>>C = [4819 4819 4819 4819 4819]
C =
    4819    4819    4819    4819    4819
```

Find the probabilities (the proportion of metal bioaccumulation coefficients):

```
>>rdivide(A,C)
ans =
    0.4358  0.1255  0.3891  0.0116  0.0380
```

Form a transition matrix:

```
>>B = [0.4358 0.1255 0.3891 0.0116 0.0380; 0.1255 0.3891 0.0116 0.0380 0.4358; 0.3891 0.0116 0.0380 0.4358 0.1255; 0.0116 0.0380 0.4358 0.1255 0.3891; 0.0380 0.4358 0.1255 0.3891 0.0116]
B =
    0.4358  0.1255  0.3891  0.0116  0.0380
    0.1255  0.3891  0.0116  0.0380  0.4358
    0.3891  0.0116  0.0380  0.4358  0.1255
    0.0116  0.0380  0.4358  0.1255  0.3891
    0.0380  0.4358  0.1255  0.3891  0.0116
```

We will assume that the starting point of time (2015) will be found by system in the state S_0. The probability of the state $p_{(0)} = 1$. Write the vector of initial states $p_{(0)}$ = (1; 0; 0; 0; 0).0.0116 0.0380 0.4358 0.1255 0.3891 0.0380 0.4358 0.1255 0.3891 0.0116

We will assume that the starting point of time (2015) will be found by system in the state S_0. The probability of the state $p_{(0)} = 1$. Write the vector of initial states $p_{(0)}$ = (1; 0; 0; 0; 0).

The implementation of the simulation will be presented in the Matlab software (Fig. 1).

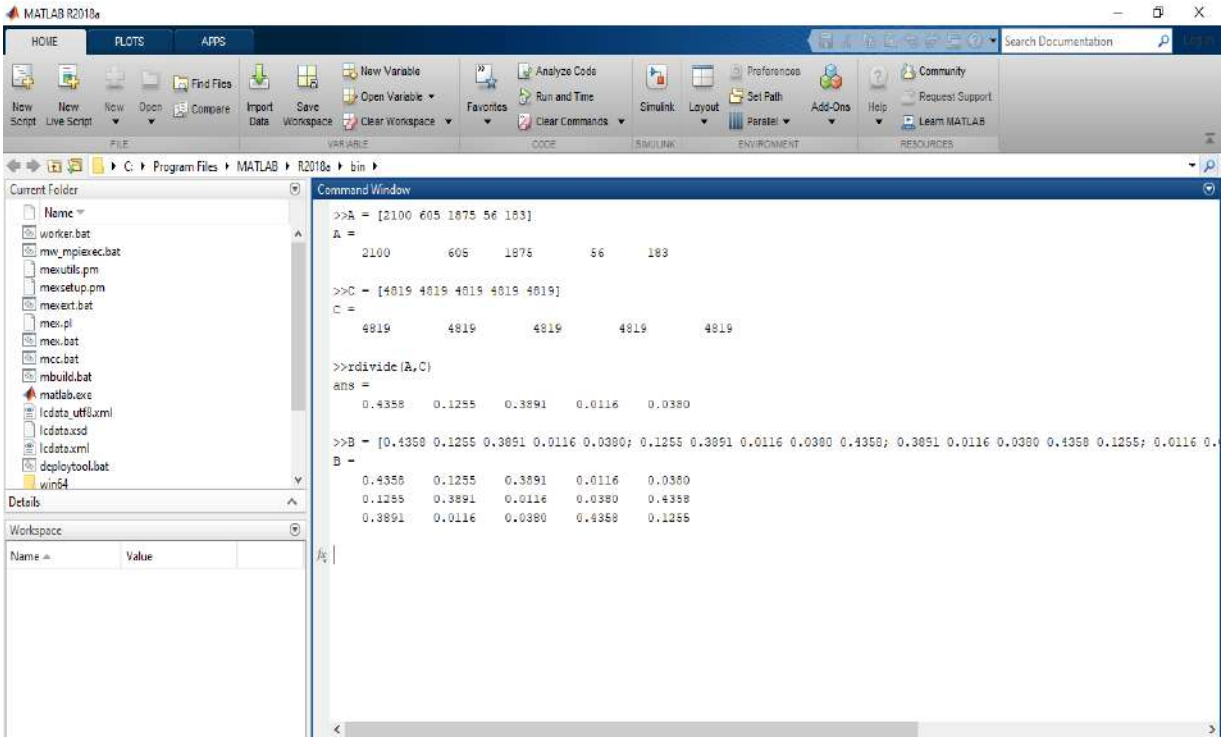

Fig.1. Visualization of modeling of metal bioaccumulation coefficients based on Markov processes in Matlab software.

Now we predict the coefficients of bioaccumulation of metals in the near future. The forecasting data implemented in the Matlab software environment will be written in the table 5.

Table 5. The results of predicting the bioaccumulation of metals are implemented in Matlab.

	P_1	P_2	P_3	P_4	P_5
K = 1	0.4358	0.1255	0.3891	0.0116	0.0380
K = 2	0.3586	0.1250	0.1956	0.1956	0.1250
K = 3	0.2551	0.1579	0.2494	0.1674	0.1702
K = 4	0.2364	0.1769	0.2049	0.2049	0.1769
K = 5	0.2141	0.1858	0.2133	0.1933	0.1936
K = 6	0.2002	0.1933	0.2021	0.2021	0.1933
K = 7	0.2038	0.1957	0.2037	0.1984	0.1984
K = 8	0.2024	0.1981	0.2007	0.2007	0.1981
K = 9	0.2010	0.1988	0.2010	0.1996	0.1996
K = 10	0.2007	0.1995	0.2002	0.2002	0.1995
K = 11	0.2003	0.1997	0.2003	0.1999	0.1999
K = 12	0.2002	0.1999	0.2001	0.2001	0.1999
K = 13	0.2001	0.1999	0.2001	0.2000	0.2000
K = 14	0.2001	0.2000	0.2000	0.2000	0.2000

The results show that in the simulation of the ecological situation of metal bioaccumulation by bivalve mollusc *Unio pictorum* L. in water with the biggest probability of 0.44 will be a Zn concentration in the amount of 2100, but we see that after 9 seasons, samples of metals in the studied reservoir with a probability of 0.2 will be the Zn concentration and approximately the same volume will be the concentration of Cu metal in the reservoir, and metals such as Pb and Cd will have approximately the same probability of 0.19, according to the modelling that we presented in the table 5. Next season, the share of Zn in the reservoir will have a probability of 0.2007. In the eleventh and twelfth seasons, the largest share of the metal concentration in the reservoir will have Zn metal, and the smallest will be the concentration of Mn metal in the reservoir. The use of economic and mathematical modelling to predict the concentration of metals in the studied reservoir will prolong the dynamics of previous studies to prognose the results.

On the basis of the input data presented in the Table 3, we model the economic situation based on Markov chain theory for the short term and how many years the situation will stabilize. The calculations will be made using Matlab.

Incoming data:

Metal	Zn	Mn	Cu	Pb	Cd
Summer/above of Ternopil city	1685	595	1833	78	107

Construct a matrix of metal bioaccumulation coefficients in Matlab.

```
>>A = [1685 595 1833 78 107]
A =
    1685    595    1833    78    107
```

Form a vector of sums:

```
>>C = [4298 4298 4298 4298 4298]
C =
    4298    4298    4298    4298    4298
```

Find the probabilities (the proportion of metal bioaccumulation coefficients):

```
>>rdivide(A,C)
ans =
    0.3920  0.1384  0.4265  0.0181  0.0249
```

Form a transition matrix:

```
>>B = [0.3920 0.1384 0.4265 0.0181 0.0249; 0.1384 0.4265 0.0181 0.0249 0.3920; 0.4265 0.0181 0.0249 0.3920 0.1384; 0.0181 0.0249 0.3920 0.1384 0.4265; 0.0249 0.3920 0.1384 0.4265 0.0181]
B =
    0.3920  0.1384  0.4265  0.0181  0.0249
    0.1384  0.4265  0.0181  0.0249  0.3920
    0.4265  0.0181  0.0249  0.3920  0.1384
    0.0181  0.0249  0.3920  0.1384  0.4265
    0.0249  0.3920  0.1384  0.4265  0.0181
```

We will assume that the starting point of time (2015) will be found by system in the state S_0. The probability of the state $p_{(0)} = 1$. Write the vector of initial states $p_{(0)} = (1; 0; 0; 0; 0)$.

We now predict the bioaccumulation coefficients of metals until the situation stabilizes.

1 step value:

```
>>p = [1 0 0 0 0]
p =
    1    0    0    0    0
```

2 step value:

```
>>p1 = [p*B]
p1 =
    0.3920  0.1384  0.4265  0.0181  0.0249
```

3 step value:

```
>>p2 = [p1*B]
p2 =
    0.3557  0.1312  0.1909  0.1909  0.1312
```

4 step value:

```
>>p3 = [p2*B]
p3 =
    0.2457  0.1648  0.2518  0.1669  0.1705
```

5 step value:

```
>>p4 = [p3*B]
```

The fragment of metal bioaccumulation coefficient prediction is shown in the Matlab software environment (Fig. 2).

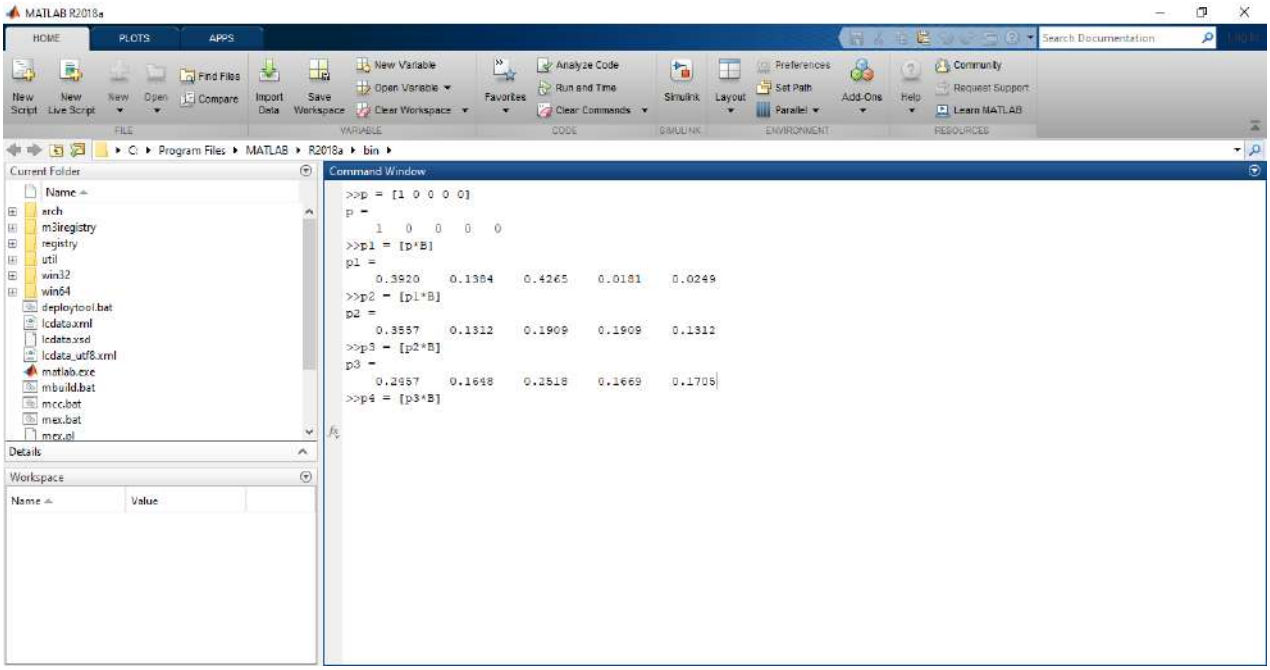

Fig. 2. Visualization of the forecasting fragment of the bioaccumulation metal coefficient states in the Matlab software environment.

And so we will carry out modeling to level the probable state of the ecological system, i. e. the optimal metal ratio in the reservoir. The simulation results are presented in table 6.

Table 6. The results of the metal bioaccumulation predicting are implemented in Matlab.

	P_1	P_2	P_3	P_4	P_5
K = 1	0.3920	0.1384	0.4265	0.0181	0.0249
K = 2	0.3557	0.1312	0.1909	0.1909	0.1312
K = 3	0.2457	0.1648	0.2518	0.1669	0.1705
K = 4	0.2338	0.1798	0.2031	0.2031	0.1798
K = 5	0.2113	0.1883	0.2125	0.1931	0.1943
K = 6	0.2079	0.1944	0.2014	0.2014	0.1944
K = 7	0.2028	0.1965	0.2030	0.1983	0.1987
K = 8	0.2018	0.1984	0.2003	0.2003	0.1984
K = 9	0.2006	0.1989	0.2006	0.1994	0.1995
K = 10	0.2003	0.1994	0.1999	0.1999	0.1994
K = 11	0.2000	0.1995	0.2000	0.1997	0.1997
K = 12	0.1999	0.1997	0.1998	0.1998	0.1997
K = 13	0.1998	0.1997	0.1998	0.1997	0.1997
K = 14	0.1998	0.1997	0.1997	0.1997	0.1997
K = 15	**0.1997**	**0.1997**	**0.1997**	**0.1997**	**0.1997**
K = 16	0.1997	0.1997	0.1997	0.1997	0.1997

The results of the simulation implemented in the Matlab software are presented in Fig. 3.

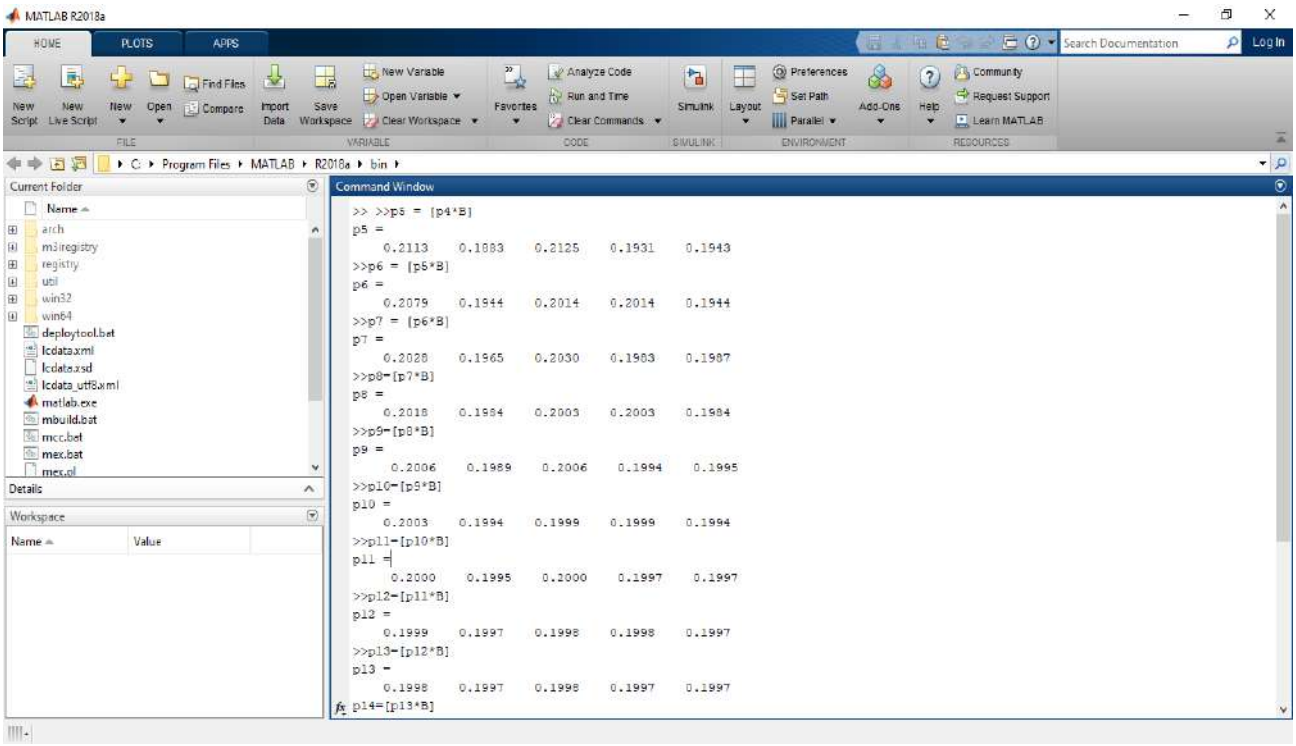

Fig. 3. Visualization of metal bioaccumulation coefficient forecasting in the Matlab software

We compare the results of forecasting the probable state of metal concentration in the reservoir for the periods of spring / above Ternopil and summer / above Ternopil, which are presented in the tables 5 and 6. The analyzing samples for spring modeling results indicate that after 9 seasons in the studied reservoir Zn concentration will more likely to be 0.2 and Cu concentration will be approximately at the same level, and metals such as Pb and Cd will approximately equally amount to 0.19. At the same modelling step for the summer period, the probable state of metal bioaccumulation is as follows: Zn – 0.2006, Mn – 0.1989, Cu – 0.2006, Pb – 0.1994, Cd – 0.1995. Thus, the reservoir will contain the most metals such as

Zn, Cu with a probability of 0.2206, a slightly lower Mn concentration, then Cd with a probability of bioaccumulation of 0.1995 and Pb – 0.1994.

The modelling results of probable state of metal bioaccumulation in the spring show that in the 10th season of water sampling, the same trend in the eleventh and twelfth seasons, the highest metal concentration in the reservoir will be Zn, and the lowest – Mn. During the summer, the situation with the probable state of metals at 10 and 11 steps of the simulation shows the highest bioaccumulation of metals such as Zn and Cu with coefficients 0.2003 and 0.1999 respectively, lower Mn concentration (0.1994) and higher Pb concentration (0.1999), and Cd at levels of Mn (0.1994). Comparing the results for spring and summer, it can be stated that the probability of optimal value of metal bioaccumulation in spring will be reached at the step 14, and in summer at the step 15 of the study, taking to account that the heavy metal ion accumulation by molluscs is an active and regulated process.

Conclusions.

The chemical composition of the river Seret waters formed by the influence of a number of factors, but seasonal and anthropogenic factors play a dominant role. In the spring season, a number of hydrochemical indicators (pH, water hardness, concentrations of NO_2^-, NH_4^+, Cl^- and ions metals) have lower values than the summer, which is primarily due to the increase in water level (spring flood).

Evidence that the Seret River is under significant anthropogenic influence is the increase in the amount of organic matter, ammonium cations, nitrite ions, chloride ions, phosphate ions and a decrease in oxygen concentration below the city of Ternopil, especially in the summer season.

An increase in the concentration of metals (Mn, Cu and Pb) in the summer below Ternopil may be caused by the discharge of insufficiently treated wastewater. The series of concentrations of metals in the water of the Seret River is as follows Mn → Zn → Pb → Cd → Cu.

The accumulation of mollusks of heavy metal ions depends on the physical and chemical characteristics of the environment of the aquatic environment. In general, the series of accumulation of metals in the tissues of molluscs *Unio pictorum* L. has the form Zn → Mn → Cu → Pb → Cd, and the coefficients of bioaccumulation of heavy metals have the following form Zn> Cu> Mn> Cd> Pb.

Using economic-mathematical modelling tools and statistical methods based on correlation-regression analysis using modern information systems of the Matlab type made it possible to identify correlations between the studied indicators and to forecast the status of water pollution in the near future.

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Long-term changes in the chemical composition of the water of the Inhulets and Saksahan rivers within the Kryvorizkyi Iron Ore Basin (1980–2020)

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Abstract. The article presents the generalized results of chemical composition research of waters from Inhulets and Saksahan rivers on the territory adjacent to the Northern and Inhulets mining and processing plants in the period of 1980–2020. Mining in Kryvyi Rih is connected with pumping of underground waters (mine and quarry), which have an abnormal chemical composition, high mineralization and contain high concentrations of microcomponents. The following scheme of mine water utilization is used in the Kryvyi Rih iron ore basin: the mines of the northern part of Kryvbas discharge water into the tailings dam of Northern Iron Ore Dressing works (Northern GZK); mines of the southern part discharge mine waters into the storage pond of the Svistunov creek during the year, and in the winter its waters are discharged into the Inhulets River with subsequent washing of the river in the spring-summer period. Such treatment of mine and quarry waters has led to the formation of a hydrochemical anomaly on the territory of Northern GZK with the center in the tailings. The mineralization of water in the pond reaches 23 g / l (2020). There is a high content of microcomponents: lead, cadmium, vanadium, manganese, boron, bromine, nickel, mercury, thiocyanates. As a result, the mineralization of the Saksahan River water increases over time (up to 5.4 g / l), the content of microcomponents also increases and becomes quite high. Prolonged use of the Inhulets River for utilization of mine water from the Svistunov creek storage pond has led to a change in the type of water: instead of type II (river water), Inhulets water belongs to the type III (metamorphosed waters). There are no regularities in the change of chemical composition of water (hydrochemical regime) in Inhulets, which is a consequence of the introduction of the scheme "discharge – flushing" for the disposal of mine water. Among the microcomponents in the water of Inhulets there is an increased content of vanadium, boron and bromine (7–8 times), single excess of lead content. The analysis of equilibria in the carbonate-calcium system of the Inhulets and Saksahan rivers confirmed that the existing hydrochemical regime for the studied rivers is stationary, thus, the environmental measures implemented will not have rapid consequences.

Keywords: Kryvorizkyi Iron Ore Basin, rivers, Inhulets, Saksahan, mine waters, chemical composition of water, monitoring

Багаторічні зміни хімічного складу води річок Інгулець та Саксагань у межах Криворізького залізорудного басейну (1980–2020 рр.)

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Анотація. У статті наведено узагальнені результати досліджень хімічного складу води річок Інгулець та Саксагань на території, прилеглій до Північного та Інгулецького гірничо-збагачувальних комбінатів у період 1980–2020 рр. Видобуток корисних копалин у Криворіжжі пов'язаний зі відкачуванням підземних вод (шахтних та кар'єрних), які мають аномальний хімічний склад, високу мінералізацію та містять високі концентрації мікрокомпонентів. У Кривбасі застосована наступна схема утилізації шахтних вод: шахти північної частини Кривбасу скидають води у хвостосховище Північного гірничо-збагачувального комбінату (ПівнГЗКу); шахти південної частини скидають шахтні води у ставок-накопичувач балки Свистунова впродовж року, а в зимовий період води з нього скидаються в р. Інгулець з подальшою промивкою річки у весняно-літній період. Таке поводження з шахтними та кар'єрними водами призвело до формування гідрохімічної аномалії на території ПівнГЗКу з центром у хвостосховищі. Мінералізація води у ставку досягає 23 г/дм^3 (2020 р.), відзначається високий вміст мікрокомпонентів: свинцю, кадмію, ванадію, марганцю, бору, брому, нікелю, ртуті, тіоціанатів. Внаслідок, цього у воді р. Саксагань з часом підвищується мінералізація води (до 5,4 г/дм^3), вміст мікрокомпонентів також зростає і стає досить високим. Тривале використання р. Інгулець для утилізації шахтних вод зі ставка-накопичувача балки Свистунова призвело до зміни типу води: замість II типу (річкові води) інгулецька вода має III тип (води метаморфізовані). Не прослідковуються закономірності у зміні хімічного складу води (гідрохімічний режим) у р Інгулець, що є наслідком впровадження схеми "скид – промивка" для утилізації шахтних вод. Серед мікрокомпонентів у воді Інгульця відзначається підвищений вміст ванадію, бору і брому (у 7–8 разів), поодинокі перевищення вмісту свинцю. Аналіз рівноваг у карбонатно-кальцієвій системі річок Інгулець та Саксагань підтвердив, що для досліджуваних річок існуючий гідрохімічний режим є стаціонарним, тому природоохоронні заходи, що впроваджуються, не матимуть швидких наслідків.

Ключові слова: Криворізький залізорудний басейн, річки, Інгулець, Саксагань, шахтні води, хімічний склад води, моніторинг.

Introduction

Iron ore mining in the Kryvorizkyi Iron Ore Basin has been going on for over 130 years. Currently, the procedure is performed by mining and quarrying with mandatory drainage. The long-term problem of Kryvyi Rih is that groundwater pumped from mines and quarries has a high mineralization – up to 160 g / l (Batkivshchyna mine) (Haletskyy, 2014).

The mine water is pumped by pumping stations from the southern mines' group to the south (12–13 million m^3 / year) and pumped entirely to the storage pond of mine water in the Svistunov creek for their temporary accumulation and subsequent discharge in the intervegetation period into the river Inhulets. After the mine water is discharged, the bed of the Inhulets River is washed with water from the Karachunivsky Reservoir, where the water is supplied by the Dnipro-Inhulets Canal (Sherstiuk, 2016).

Mine waters are pumped north (3.0–4.0 million m^3 / year) from the northern group of mines into the tailings of the Northern Mining and Processing Plant (MPP), where it is used in the plant's circulating water supply cycles.

According to any scheme, as a result of pumping mine water, hydrochemical anomalies are formed on the earth's surface. In the Svistunov creek, the accumulated mineralization of water reaches 38 g / l. Waters of the northern group of mines with mineralization up to 45 g / l are discharged into the tailings pond of the Northern MPP, as a result of which the mineralization of water in the circulating water supply pond reaches 20 g / l. The Inhulets and Saksahan rivers are in close proximity to the territory of iron ore mining, beneficiation and processing.

The aim of the study

The aim of the study is to analyze changes in the chemical composition of the Inhulets and Saksahan rivers, located in the region of mining industry, for the period of 1980–2020. During this time, many environmental measures have been implemented in Kryvyi Rih region, that must have brought positive changes to the chemical compound of rivers water.

Materials and methods of research

The initial data for the study are the results of chemical analyzes of water samples taken by the state enterprise "Ukrchormetgeologiya". To process the results of chemical analyzes of water samples, researchers used traditional methods for determining the type of water by Kurlov and Alekin. Equilibria in the carbonate-calcium system of river waters are estimated according to the known thermodynamic schemes (Khilchevskyi, Osadchyi, Kurylo, 2012). Graphic constructions are made both in the forms of traditional for hydrochemical researches and in the forms proposed by the authors.

The theoretical basis of the research is a systematic approach to the study of landscapes and its components, which are natural waters. An important feature of the landscape – coherence follows from the system approach, that is the correspondence of its various components to each other (Perelman, 1999).

The coherence (system unity) of the landscape determines the presence of feedback on the migration of atoms, which determines the integrity and qualitative originality of the landscape, and the existence of self-regulation in it. The components of the landscape interact each other and strive for a state in which the consumption of matter, energy and information would be equal to their receipt. As a result, the landscape is a self-regulating system, which in conditions of constant supply of matter and energy seeks to achieve a stable state. This possibility is provided by the fact that the landscape consists of subsystems that have feedback. Subsystems, in turn, function as systems with autoregulation, and this quality gives the macrosystem -landscape – a significant susceptibility to internal and external impulses.

In the landscape, the processes of self-organization determine the durability, stability of the structure and functions, their preservation when changing external conditions. If a certain natural or natural-technogenic system has reached a steady state, then according to the principle of Le Chatelier, it seeks to change in such a way as to minimize the effect of external influences. It is necessary to take into account such stationary states both for the analysis of the existing hydrochemical situation and for the design of environmental measures. A non-stationary system in which equilibria have not yet been established is easier to manage than a system with stationary hydrochemical processes.

Systematic approach in the study of natural systems known as "centralized", which have a characteristic "structural center", is extremely important. In natural and natural-technogenic landscapes, the structural center determines the geochemical features of landscapes of lower hypsometric levels. In Kryvyi Rih region, the highest hypsometric marks are most often found in tailings, which are a geochemical anomaly and cause the formation of geochemical halos in landscapes.

Results and analysis

Currently, about 300 deposits of rich ores are known in Kryvorizkyi Iron Ore Basin, which are united in 25 deposits within the basin. Some of them have already been worked out. In total, 5.5 billion tons of iron ore have been extracted since the beginning of industrial development of the Kryvorizkyi Iron Ore Basin subsoil, and another 231.6 million tons have been explored

in the depth range from 1500 to 2000 m. The average iron content in them is 53.83 %. Currently, in mines with underground extraction of raw materials, work is carried out in the depths of 800–1350 m, and preparatory work – in the limit depths for the current technology. At the beginning of the XXI century the basin contained 9 mines, 5 mining and processing plants that conduct ore mining in 9 quarries.

To increase the iron content in the final product (iron ore concentrate and pellets) to 60–66 %, the technological scheme of magnetite quartzite enrichment is used. Enrichment waste or tailings (pulp) are stored in tailings hydraulically.

Tailings are usually arranged in depressions – gorges, ravines, depressions at a distance of several kilometers from the concentrator. The tailings pond is fenced off by a dam, which is washed away from the tails and additionally strengthened. It gradually settles the solid phase of the "tails", sometimes with the help of reagents that are added specifically – coagulants and flocculants. Settled waters are accumulated in circulating water ponds, is treated and discharged into local water bodies or returned to the concentrator for reuse in technological processes (Sherstyuk, 2011).

The natural-technogenic complex of the Northern MPP includes a tailings pond and a section of the Saksahan River (Fig. 1).

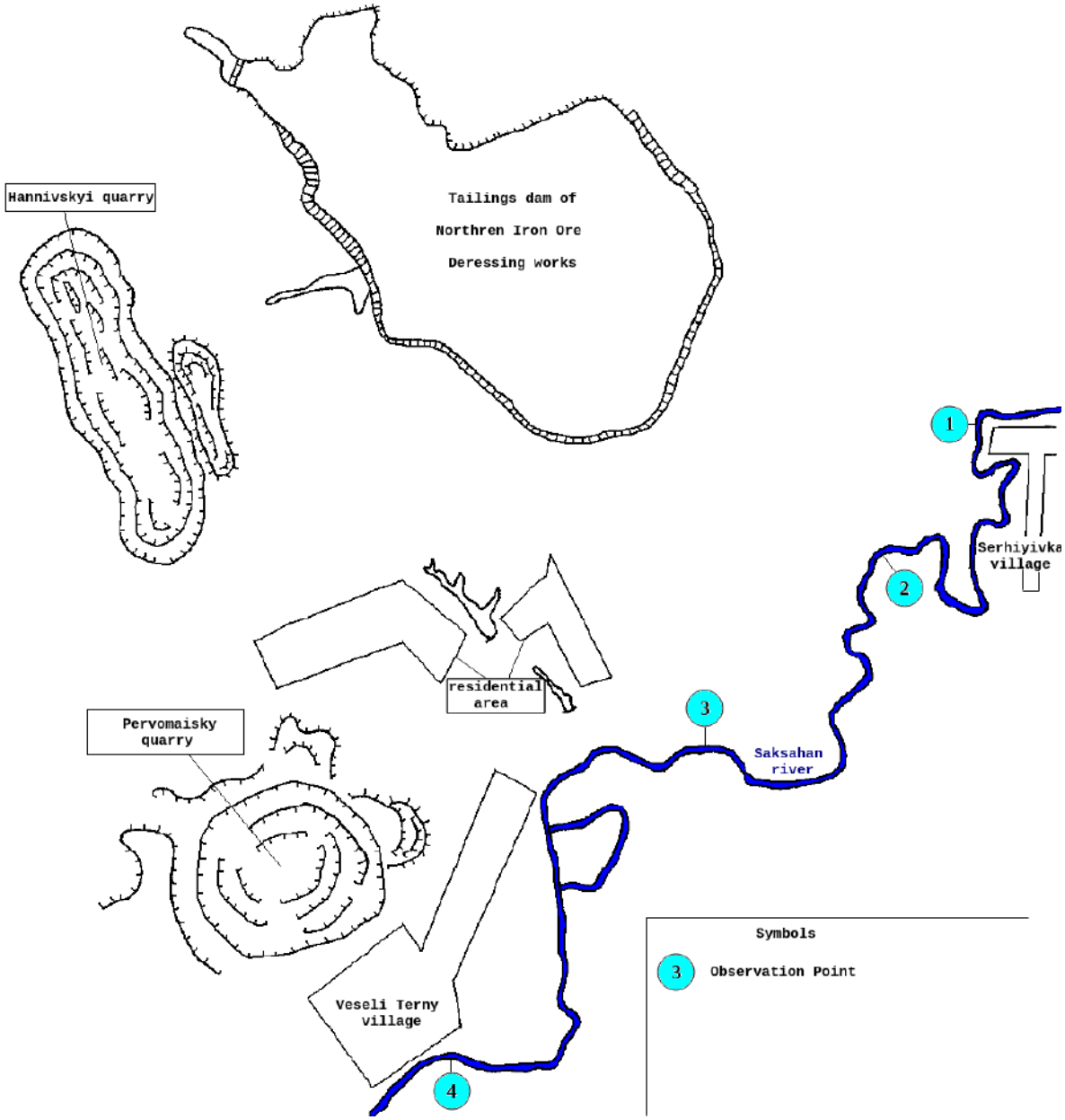

Fig.1. Map of Saksahan river in the district of Northern Iron Ore Processing Plant in Kryvbas with observation points for chemical composition of river water (downstream) No. 1 – Motyna creek; No. 2 – the first water meter post; No. 3 – the second water meter post; No. 4 – Veseli Terny village

The Northern MPP tailings pond has been operated since 1963. The main dam of the Northern MPP tailings pond is located at a distance of 2.5 km from the mouth of the Petrykov creek, which flows into the Saksahan River. Also, in Petrykov creek along the outer contour of the right-bank enclosing dam, tailings, two emergency tanks were created: the first one is in the western part and the second one is in the northern part of the tailings. The area of the tailings pond is 1295 ha (of which the tailings pond itself is 980.0 ha, the circulating water pond is 315.0 ha). The length of the tailings pond is 17.3 km (tailings pond – 11.0 km, circulating water pond – 6.3 km). The contour of the tailings pond is closed by a 1.2 km long dividing dam, which separates the circulating water supply pond from the tailings pond itself. In addition to sludge pulp, quarry water (2.5 million m^3 / year), mineralization mine water (5.5 million m^3 / year), wastewater from treatment plants (36.15 thousand m^3 / year), and precipitation are discharged into the tailings pond, and surface filtration waters that were made from drainage systems built around the storage. (Sherstyuk & Khilchevskyi, 2012).

The water in the tailings is going through the closed cycle: the pulp (tails and water) comes from concentrators; the pulp is distributed on alluvial maps; after settling the tailings, the water enters the compartment where the pond of the circulating water supply is located, where it is fully lit and pumped to the concentrator for reuse.

To replenish the volume of the plant's circulating water supply system, quarry water from the Pervomaisky and Hannivsky quarries of the Northern MPP, as well as the water from the northern group of Kryvbas mines is constantly supplied to the tailings pond.

In low water years, the volume of the circulating water supply system can be replenished by attracting domestic wastewater from the northern aeration station of the Kryvyi Rih and water supply from the Saksahan River from the shore pumping station of the plant. (Optimizatsiia …, 2017)

With a closed water supply scheme of the plant in the tailings pond, an excess of return water is periodically formed. In order to avoid emergencies, the company periodically discharges excess return water into the Saksahan River.

The excess of return water from the tailings into the Saksahan river is discharged by two water outlets, which are located on the right bank of the river, 48 and 50 km from its mouth, respectively, downstream from the Serhiyivka village. (Optimizatsiia …, 2017).

In 2010, the water-salt balance of the tailings was calculated (Sherstyuk & Khilchevskyi, 2012) and it was concluded that under the current regime of discharges into the tailings, the mineralization of water in the pond of circulating water supply will increase. The data availability after 2010 allowed to assess the trend of changes in mineralization and chemical composition of water. As of 2020, the salinity of water in this pond reached 23.4 g / l, water type Cl^{Na}_{III}. Since the most important hydrochemical process in the tailings is mixing, it is advisable to assess the tendency of water mineralization to change the rate of circulating water supply over time. The regression equation has the form of:

$$M = 0.93X + 4975 \ (R^2 = 0.81), \quad (1)$$

where X is the day from the beginning of discharges into the mine water reservoir – 1978 (Fig. 2).

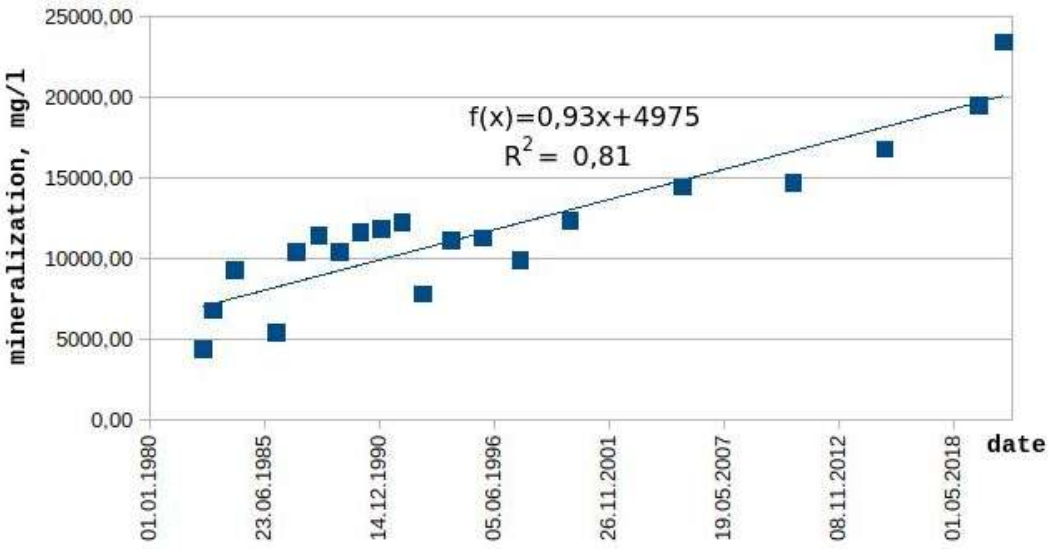

Fig. 2. Change of water mineralization in the pond of circulating water supply in the tailings of the Northern Iron Ore Processing Plant during 1980–2020 and the corresponding trend, Kryvbas

The equation allows to identify the main trend of change in water mineralization in the circulating water supply rate and to estimate its intensity. Continuation of this mode of the tailing use with the discharge of mine water with a salinity of 40–44 g / l will further lead to an increase in water salinity by 340 mg / l per a year. It should be noted that the regression equation is not predictive, but only allows to estimate the direction of the process. A more accurate forecast of changes in the chemical composition of water in the rate of circulating water supply of the tailings can be made on the basis of the calculation of water-salt balance.

It should be noted that the water rate of the reversible water supply of the tailings also has an increased content of microcomponents: lead, cadmium, vanadium, manganese, boron, bromine, nickel, mercury, thiocyanates.

The microelement composition of the current enrichment waste of the Northern MPP in the non-magnetic fraction is more than 0.03 mm (g / t): manganese – 700; lead – 4; vanadium – 6 (Gubina & Zaborovskyj, 2015).

According to research (Savosko, 2016), the aerial emission of heavy metals of the Northern GZK from the activities of quarries, concentrators, tailings is: manganese 26.9 t / year, nickel – 537.1 kg / year, lead – 574 kg / year, cadmium – 5.1 kg / year.

Thus, heavy metals enter the tailings water from the tailings. Microcomponents such as boron and bromine enter the tailings pond with mine waters.

Saksahan river. Saksahan flows in the southeastern part of the Dnipro Upland. The left tributary of the Inhulets belongs to the category of small rivers. Its source is located near the Malooleksandrivka village of the Upper Dnipro district of the Dnipropetrovsk region at an altitude of 153 m above sea level. In the middle of the twentieth century the length of the Saksahan River was 144 km, the area of the basin was 2 025 km. The river has an unbranched channel, its predominant width is 20–40 m (except for the Kresivske and Makortivske reservoirs). The flow velocity is negligible. The river has undergone significant changes as a result of the development of the mining industry. Since 1953, the mining industry began to develop intensively, new quarries were laid, namely the quarry of the Central Mining Company MPP. To organize its operation, the downstream of the Saksahan river was directed into an underground tunnel with a diameter of 3.5 m and a length of 5.32 km. As a result, Saksahan flows into the Inhulets 1.43 km below its natural mouth (Sherstiuk & Khilchevskyi, 2012). Currently, the length of the river is 140 km, the area of the basin is 1970 km^2.

At the research site on the Saksahan River, which is 25 km long, there are 4 observation points (OP) for the chemical composition of river water (from top to bottom): OP No. 1 – Motyna creek; OP No 2 – the first water meter post; OP No 3 – the second water meter post; OP No 4 – Veseli Terny village (see Fig. 1).

It should be noted that the right bank of the Saksahan river is located at a distance of 2.5 km from the tailings of the Northern MPP, which has a high (135 m) absolute mark and is the geochemical center. In addition, the Saksahan runoff is artificially blocked in accordance with the Ihulets river washing regulations (during the irrigation season) (Indyvidualnyi rehlament …, 2018). Significant changes in the hydrological regime of the river (construction of reservoirs, discharges of excess water from the tailings, runoff) have a decisive influence on the formation of the water chemical composition.

In the river Saksahan – OP No 1 (Motyna creek) there is a constant increase in water mineralization from 1.1 g / l in 1980 to 4.2 g / l in 2020 (Table 1). The linear approximation of this process is well described by the linear equation:

$$M = 0.19X + 1389.1 \ (R2 = 0.84), \quad (2)$$

X – day, since 1987.

Table 1. Change in mineralization and hydrochemical type of water in the river Saksahan during 1980–2020.

Observation point On Saksahan river	Mineralization of water, g/l		Hydrochemical type of water	
	1980 p.	2020 p.	1980 p.	2020 p.
OP No 1 – Motyna creek	1.1	4.2	S^{Ca}_{III}	S^{Na}_{II}
OP No 2 – the first water meter post	1.7	5.4	S^{Na}_{II}	S^{Na}_{II}
OP No 3 – the second water meter post	1.8	4.0	S^{Na}_{II}	S^{Na}_{II}
OP No 4 – Veseli Terny village	1.7	3.6	S^{Na}_{II}	S^{Mg}_{III}, Cl^{Na}_{III}

The type of water gradually changes from S^{Ca}_{III} to S^{Na}_{II}, with a tendency to precipitate $CaCO_3$ and the carbonate system reaches equilibrium. Such changes in the chemical composition of water and in the carbonate-calcium system indicate that the hydrochemical processes have acquired the features of stationarity since 2010.

In the river Saksahan – OP No 2 (the first water meter post) from 1980 to 2020 water salinity increased from 1.7 g / l to 5.4 g / l, the type of water in most samples remains unchanged – S^{Na}_{II}, carbonate-calcium system is prone to precipitation. This may indirectly indicate a greater anthropogenic impact in this section of the river than upstream (in OP No 1 – Motyna creek). The tendency of water mineralization change in time is approximated by the linear regression equation: $M = 0.26 X + 1085.2$ ($R^2 = 0.77$) – Fig. 3 (X - days, since 1988).

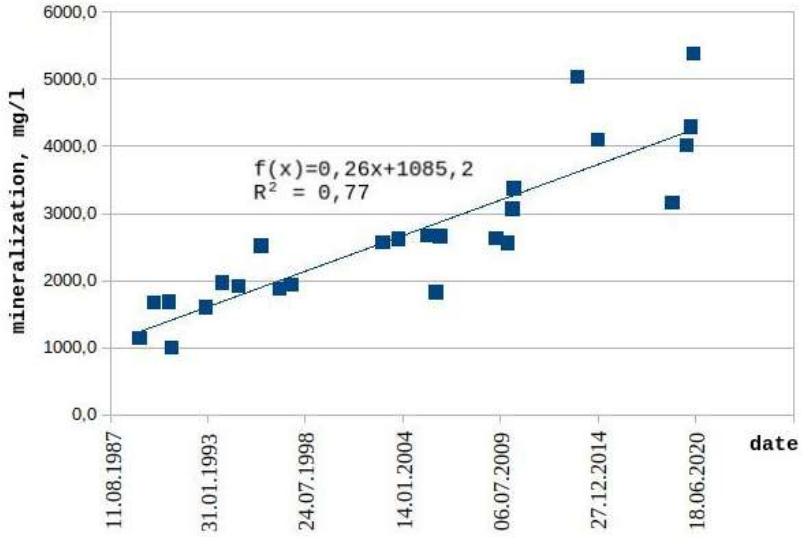

Fig. 3. Change of mineralization of water in the Saksahan river – OP No 2 (the first water meter post) in the area of Northern Iron Ore Processing Plant, Kryvbas

In Saksahan – OP No 3 (second water meter post) water mineralization varies from 1.8 g / l in 1980 to 4.0 g / l in 2020, water type for the whole time of S^{Na}_{II} observations, carbonate-calcium the system is equilibrium. The regression equation describing the change in mineralization over time has the form:

$$M = 0.16\ X + 1710.4\ (R^2 = 0.65), \quad (3)$$

X – day, since 1988.

Water sampling in the Saksahan river – OP No 4 (Veseli Terny village) was performed until 2015. From 1980 to 2015, the mineralization of river water increased from 1.7 g / l to 3.6 g / l, water type varied from S^{Na}_{II} to S^{Mg}_{III} and Cl^{Na}_{III}, which reflects the combined effect of the Northern MPP and Veseli Terny village. The carbonate-calcium system is prone to precipitation during the predominant period of time. A number of hydrochemical observations are described by the regression equation:

$$M = 0.16\ X + 1479.0\ (R^2 = 0.79), \quad (4)$$

X – day, since 1987.

Regarding microelements in the water of the Saksahan River, the content of which exceeds the maximal permissible concentrations (MPC) for water bodies for drinking and cultural use, the same set is observed as in the tailings, namely: lead, cadmium, manganese, boron, bromine, nickel, mercury, thiocyanates.

As a result, it can be noted that a stable hydrochemical anomaly has formed on the territory of the Northern Iron Ore Processing Plant. Its center is a tailings pond, when remote from it, the intensity of increasing water mineralization in Sakasahan decreases, and hydrochemical processes in the river water become equilibrium. Environmental protection measures in this area should be aimed primarily at stopping the discharge of mine water into the tailings, their demineralization.

Inhulets river. The hydrological and hydrochemical regime of the Inhulets river within Kryvbas has been completely transformed. Intensive mining of iron ore inevitably raises the question of pumping mine and quarry water. Until 1993, highly mineralized mine waters were discharged directly into the Inhulets river in volumes of 40 to 60 million m^3 annually (Khilchevskyi, Kravchynskyi, Chunarov, 2012).

From 2011 to the present time, a scheme of year-round accumulation of mine waters of the southern group of mines in the storage pond of the Svistunov creek with their subsequent discharge into the Inhulets river in the intervegetation period has been introduced. The discharge of annual surpluses of return waters of the mining enterprises of Kryvbas in Inhulets river is regulated by the orders of the Cabinet of Ministers of Ukraine. (Optimizatsiia …, 2017).

Currently, the following scheme of using Inhulets for utilization of mine waters has been introduced: in winter, excess Kryvbas mine water is discharged from the Svistunov creek reservoir, which accumulates in it during the year. In the process of discharging mine water into the bed of the river Inhulets, through the Dnipro-Inhulets channel, Dnipro water is supplied. After the mine water is discharged (in the end of February), the process of washing the Inhulets riverbed with water from the Dnipro-Inhulets canal begins (in early April). Flushing lasts until mid-August.

This measure makes it possible to use Inhulets water during the growing season for irrigation of agricultural lands in Snihurivsky and Vitovsky districts of Mykolaiv region through the channels of Inhulets irrigation system, which is located in the lower reach-

es of Inhulets in Mykolaiv region. At the same time, the Ministry of Environmental Protection and Natural Resources of Ukraine warns: "… since August the water of the Inhulets River has a tendency of a sharp increase in chloride content to 1000–2000 mg / l …" (Ministry of Environmental Protection …, 2020). That is, this scheme of water use does not fully meet the requirements for water quality in Inhulets during the year.

In our study, we used the results of hydrochemical observations in the section of the Inhulets river near the Inhulets MPP, downstream from the discharge of mine water from the Svistunov creek (Fig. 4). Hydrochemical observations were carried out at different times in different observation points, so the following observation points were selected for analysis, which have the longest and most complete series: OP No 1 – bridge; OP No 2 – well 1726; OP No 3 – riffle; OP No 4 – Andryivka village.

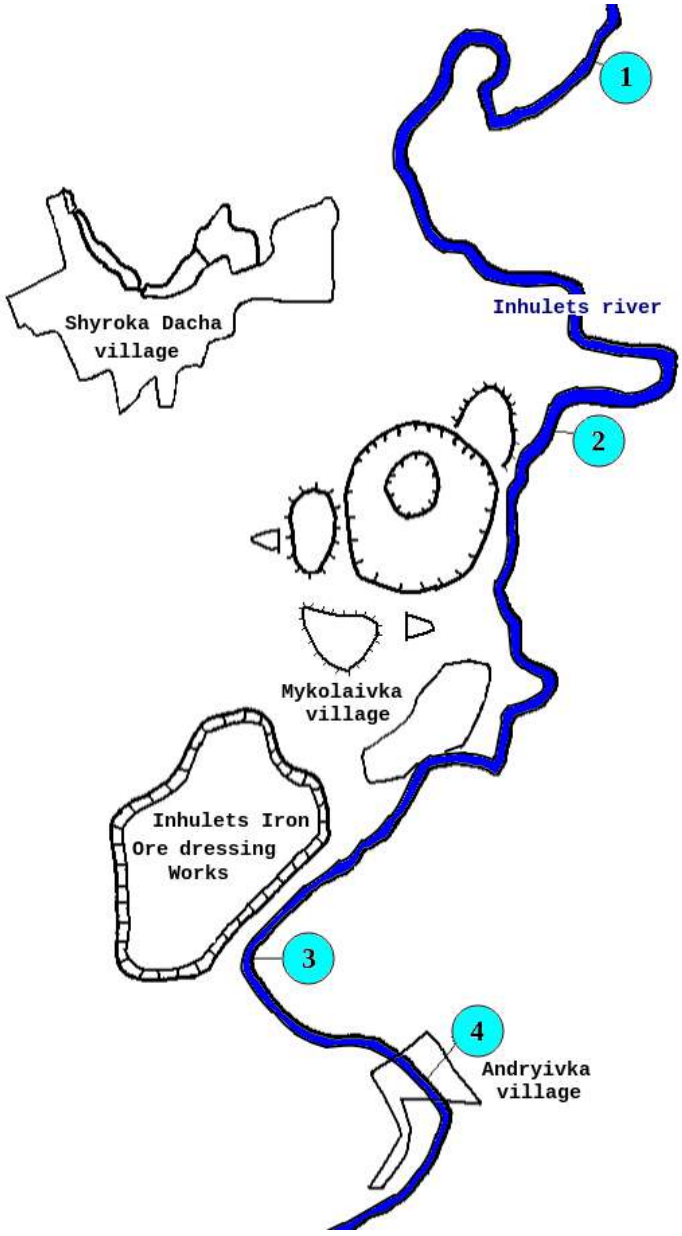

Fig. 4. Map of the Inhulets River in the area of the Inhulets Iron Ore Processing Plant in Kryvbas with observation points for the chemical composition of river water (downstream): No 1 – bridge; No 2 – well 1726; No 3 – riffle; No 4 – Andryivka village

The Inhulets Mining and Processing Plant was built on the basis of the Inhulets Magnetite Quartzite Deposit and put into operation in 1961–1966 with an annual productivity of 18.0 million tons of raw ore. In 1967–1970, 1975, 1986, 1997, 2004–2006, projects were developed and implemented aimed at increasing and maintaining the production capacity of Inhulets MPP with an annual program of raw ore production of up to 34.5 million tons and the production of concentrate up to 14.1 million tons.

Iron ore is mined from a quarry. Quarry water is pumped into the tailings pond with subsequent use in the cycle of circulating water supply of concentrators of Inhulets MPP.

The results of chemical analysis of water samples were calculated by known methods (Khilchevskyi, Osadchyi, Kurylo, 2012; 2019) to obtain the Kurlov's formula and Alekin index, equilibria in the carbonate-calcium system were determined. It draws attention to the fact that the vast majority of water samples from the Inhulets river during observations (since 1990) belong to the chloride class, sodium group, type III, i. e. are metamorphosed. Thus, the chemical composition of water was formed as a result of mixing.

It should also be noted that at any of the observation points in the fluctuations of water mineralization is not determined by a significant linear trend (by the coefficient of determination). The calcium-carbonate system is mainly in a state of equilibrium and precipitation, with isolated states of dissolution.

In the Inhulets river – OP No 1 (bridge) water mineralization varies from 1.1 g / l (1994, April) to 4.3 g / l (April 2002) (Fig. 5), the total hardness reaches its maximal value in September 2020 (34 mmol / l).

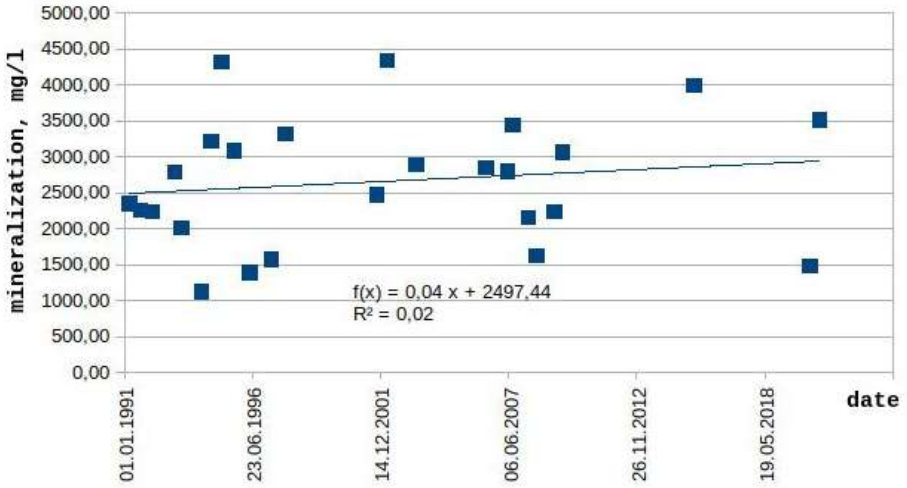

Fig. 5. Change of mineralization of water of Inhulets river – Substation No 1 (bridge) in the area of Inhulets Iron Ore Processing Plant, Kryvbas

Downstream in the Inhulets River – OP No 2 (well 1726) the mineralization of water in Inhulets varies from 1.7 g / l (2008, April) to 5.5 g / l (2019, September), the total hardness in the same time has a maximum value of 40 mmol / l. High mineralization of Inhulets water is observed after the completion of washing with Dnipro water (August 10, 2019) and low rainfall in August and September 2019.

In Inhulets river – OP No 3 (riffle) water mineralization varies from 1.6 g / l (2009, May) to 5.4 g / l (2019, September), with a total hardness of 40 mmol / l.

In the Inhulets river – OP No 4 (Andryivka village) there are no such significant fluctuations of water mineralization as in the observation points upstream. The water mineralization here varies from 1.5 g / l in April 2020 to 3.1 g / l in September 2009. The water type in about 40 % of samples varies from Cl^{Na}_{III} to S^{Na}_{II}.

Among the microcomponents there is an increased content of vanadium, boron and bromine in Inhulets water (exceeding the MPC by 7–8 times for water bodies for drinking and cultural use), there are isolated excesses of lead content.

As a result, it should be noted that the applied scheme of mine water utilization due to their discharge into the Inhulets river and its subsequent washing changed the hydrochemical profile of the river. There is a natural decrease in water mineralization downstream: the chloride class of water changes to sulfate, which is typical of most rivers of the Middle Dnieper (Khilchevskyi, Kurylo, Sherstyuk, 2018; Khilchevskyi, Kurylo, Zabokrytska, 2020), and most importantly – the type of water from III (metamorphosed water) changes to II (river water).

However, it should be noted that according to the calculations (Indyvidualnyi rehlament …, 2018) obtained in the control area (village Andryivka, state control post), drinking and cultural standards of water quality must have a volume of water 1040.4 million m^3 or water flow in the river 104.7 m^3 / s. But the supply of such a volume of water from the Karachunivsky Reservoir is impossible both from a technical and economic point of view.

In 2020–2021, an alternative scheme (regime) of accumulation of the remnants of circulating mine water in the storage pond of the Svistunov creek and their discharge into the Inhulets River will be provided. It is proposed to increase the time of discharge of mine water in the Inhulets River, increase the amount of water for

dilution, exclude the period when the river had a minimal flow after the discharge period. This approach is likely to change the hydrochemical regime of Inhulets, but will not solve the problem completely.

In our opinion, the only effective way to dispose mine water is their demineralization. It is clear that this approach has been repeatedly considered and has certain disadvantages (utilization of salts formed; energy consumption, etc.).

Conclusions

1. In Kryvyi Rih there is a dangerous ecological and hydrochemical situation due to the existence on the earth's surface of water bodies with abnormally high mineralization and ion content, which are elements of intensive biological accumulation (S, Cl, Br).

2. On the territory of the Northern Mining and Processing Plant, the geochemical center is a tailings pond into which mine (40–45 g / l) and quarry waters, as well as waters from concentrators and other sources are discharged. Water salinity in the pond of the circulating water supply of the tailings as of 2020 reaches 23.4 g / l, water type Cl^{Na}_{III}.

3. When the tailings pond of the Northern MPP overflows, return waters are discharged into the Saksahan river with water discharges from the Makortovsky Reservoir, which worsens the ecological and hydrochemical situation in the river.

4. Mineralization of water of the Saksahan River (on the territory of the Northern MPP) from 1980 to 2020 increases with intensity from 0.24 to 0.16 g / l per a year, water belongs to the sulfate class, sodium group, type II.

5. The content of microelements in the water of the Saksahan river exceeds the maximal permissible concentrations for water bodies for domestic and cultural use: lead, cadmium, manganese, boron, bromine, nickel, mercury, thiocyanates.

6. The hydrological and hydrochemical regime of the Inhulets River below the Karachunivsky Reservoir has been radically changed: there is no low winter limit with increased water mineralization; instead, there are maximum water consumption and high mineralization (due to mine water discharges); instead of high spring floods with minimal mineralization – low costs (natural) with high water salinity; summer mean water with low costs and high water salinity is replaced by high costs with minimal water salinity (due to the regime of river washing).

7. The difficulty of studying, and more predicting, the hydrochemical regime of Inhulets is the lack of a natural analogue, which would greatly facilitate the development of the optimal possible discharge of mine water.

8. The consequence of the application of the "discharge-flushing" regime for Inhulets is the absence of any regularity in the change of mineralization and chemical composition of water in the area near Inhulets Mining and Processing Plant. It is constant that in most observation points the water belongs to the chloride class, sodium group, type III, i. e. is metamorphosed.

9. The equilibrium carbonate-calcium system formed in the water of the Saksahan and Inhulets rivers indirectly confirms the equilibrium of the entire hydrochemical system. This must be taken into account when implementing environmental measures, as the system will try to return to the equilibrium it currently has.

10. It is necessary to carry out constant hydrochemical monitoring of all technogenic waters entering natural water bodies.

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Intra-annual and long-periodic components in the changes of precipitation over the Antarctic Peninsula and their possible causes

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Abstract. In order to identify and study the main mechanisms of the formation of atmospheric precipitation, in the article the monthly and annual amounts of precipitation were analyzed from the observations results at Vernadsky, Bellingshausen and Grytviken stations. For the last station, a small linear trend of precipitation increase was detected, while at Vernadsky and Bellingshausen station it is practically absent. At the next stage of the study, the characteristics of intra-annual component of the precipitation variability for these stations were obtained. In the annual course, the component of precipitation variability is represented by 3 peaks – March, July and October (at Bellingshausen station March and July only), with a well-pronounced 4-year periodicity. However, data from Vernadsky station indicates a decrease of the seasonal component in time, at Grytviken station the seasonal component is stable, while at Bellingshausen station is increasing of the seasonal component in time. The analysis of long-period components of the precipitation variability of was carried out on the remains of the data obtained after the analysis of the intra-annual component. For the long-period component of precipitation variability at Vernadsky station, five statistically significant harmonics were obtained, which are reflected in periods of 6.8, 2.4, 4.0, 5.1, and 5.3 years. For Grytviken and Bellingshausen stations, 4 statistically significant harmonics were obtained, the periods of which are 4.2, 0.8, 1.7, 8.9 years and 1.5, 2.0, 2.8, 0.2 years, respectively. Today, the main phases of solar activity are well known, which are about 11 years old. The long-period components of precipitation variability obtained in the work for the stations under consideration (to 10.3, 12 and 34.1 years) are identical (close) to the mentioned phase of solar activity. This allowed the authors to draw preliminary conclusions about the influence of solar activity on the conditions for the formation of precipitation in the region under study. However, direct correlation analysis did not confirm this, as in the case of the El Niño influence.

Keywords: atmospheric precipitation, intra-annual distribution, long-period precipitation variability, solar forcing, El Niño.

Сезонні і довгоперіодичні складові у зміні кількості атмосферних опадів в районі Антарктичного півострова та їх можливі причини

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Анотація. З метою виявлення і дослідження основних механізмів формування атмосферних опадів, у статті проаналізовано місячні та річні суми опадів за результатами спостережень на станціях Вернадський, Беллінсгаузен та Грютвікен. Для останньої станції виявлено невеликий лінійний тренд до збільшення опадів, тоді як на станціях Вернадський та Беллінсгаузен він практично відсутній. На наступному етапі дослідження були отримані характеристики внутрішньорічної складової мінливості опадів для цих станцій. У річному ході складова мінливості опадів представлена 3 піками, що припадають на березень, липень та жовтень (на станції Беллінсгаузен максимуми опадів лише у березні та липні), з чітко вираженою 4-річною періодичністю. Однак, дані зі станції Вернадський свідчать про зменшення сезонної складової в часі, на станції Грютвікен ця складова стабільна, тоді як на станції Беллінсгаузен сезонна складова мінливості опадів зростає в часі. Аналіз довготермінових компонентів мінливості опадів проведено за залишками даних, отриманих після аналізу внутрішньорічної складової. На станції Вернадський отримано п'ять статистично значущих гармонік, які відображені в періодах 6,8, 2,4, 4,0, 5,1 та 5,3 року. Для станції Грютвікен та Беллінсгаузен були отримані по 4 статистично значущих гармоніки, періоди яких становлять 4,2, 0,8, 1,7, 8,9 років і 1,5, 2,0, 2,8, 0,2 роки відповідно. Сьогодні добре відомі основні фази сонячної активності, яким близько 11 років. Довгострокові компоненти мінливості опадів, отримані в роботі для розглянутих станцій (до 10,3, 12 та 34,1 року), ідентичні (близькі) до згаданої фази сонячної активності. Це дозволило авторам зробити попередні висновки про вплив сонячної активності на умови утворення опадів у досліджуваному регіоні. Однак прямий кореляційний аналіз не підтвердив цього, як у випадку впливу Ель-Ніньо.

Ключові слова: атмосферні опади, внутрішньорічний розподіл, компоненти довгострокової мінливості опадів, сонячна активність, Ель-Ніньо.

Introduction.

Changes in rainfall and other forms of precipitation will be one of the most critical factors determining the overall impact of climate change. Precipitation is much more difficult to predict than temperature but there are some statements that scientists can make with confidence about the future. As we know (Trenberth 2011; Lapin et al. 1995; Shukla et al. 2019; Stocker et al. 2013, etc.), changes in precipitation amount during global warming will not be uniform. According to the RCP8.5 scenario (van Vuuren et al. 2011) (The recently published «U. S. National Climate Assessment» shows that we are currently on track for RCP8.5 (Hayhoe et al. 2018)), by the end of this century in high latitudes and the equatorial part of Pacific Ocean, an increase in the average annual rainfall is likely to take place. In many arid regions of mid-latitudes, as well as in subtropics, the average rainfall is likely to decrease, while in many humid regions of mid-latitudes, it is likely to increase by the end of this century (Pachauri et al. 2014). For much of Europe, wetter winters are expected, but with drier summers over central and southern Europe.

The aim of the article is to identify and study the main mechanisms of the formation and changing of the Antarctic Peninsula precipitation as well as searching of their possible causes.

Review of previous research.

Today there are a big number of publications about precipitation (Averyanov 1990; Sedunov 1991; Bogdanova et al. 2007; Klok 2010, 2013; Thomas 1963; Kirchgäßner 2011; Bromwich 1988; Bryazgin 1982, Cullather et al. 1996; Turner et al. 1995, 1998), but their regional and local features are individual, and they have not been studied enough. Different climate models are in broad agreement about future warming on a global scale, but when it comes to predicting how these changes will affect precipitation amount – there is less agreement at a detailed level. This is especially true of the Polar Regions. For example, current climate models typically represent atmospheric processes only down to scales of about 50–100 km. This limits their ability to incorporate the effects of mountains and coastlines and means that small-scale processes, such as convection, must be represented by average approximations. In addition, the latest regional climate models capture daily rainfall on large scales but are not good at capturing heavier or more localized events (Raveendranathan, 2018).

In addition, it can be assumed that under the conditions of modern climate change, the characteristics of atmospheric precipitation are also undergoing significant changes and require constant updating. All of the above indicates the importance and urgent need to study precipitation, especially in Polar Regions – areas with difficult weather circumstances: long winters, heavy snowfalls, active dynamic conditions.

Snow and other precipitation are the main component the glacial mass gains. According to the estimates by many scientists (Velicogna 2009; Mouginot et al. 2019; Rignot et al. 2019) the ice sheets today are significantly reduced due to thawing. Over the past two decades, the Greenland and Antarctic ice sheets have lost mass (high confidence). Glaciers continued to decline almost all over the world (high confidence). The area of spring snow cover in Northern Hemisphere continued to decline (high confidence). There is a high degree of confidence of the significant regional differences of Antarctic sea ice area trend, and it is very likely that the total sea ice area is increasing (Turner et al. 2014).

The glaciers losing mass, and this contributed to the sea level rise throughout the XX century. It is very likely that the rate of weight loss by the Greenland Ice Sheet increased from 1992 to 2011, which led to more significant rates of total glacial ice loss during 2002–2011 than from 1992 to 2011. The decadal mass balance of Greenland Ice Sheet switched from a mass gain of +47 ± 21 Gt/y in 1972–1980 to a loss of 51 ± 17 Gt/y in 1980–1990. The mass loss increased from 41 ± 17 Gt/y in 1990–2000, to 187 ± 17 Gt/y in 2000–2010, to 286 ± 20 Gt/y in 2010–2018, or six fold since the 1980s, or 80 ± 6 Gt/y per decade, on average. The total Antarctic Ice Sheet mass loss increased from 40 ± 9 Gt/y in 1979–1990 to 50 ± 14 Gt/y in 1989–2000, 166 ± 18 Gt/y in 1999–2009, and 252 ± 26 Gt/y in 2009–2017. In 2009–2017, the mass loss was dominated by Amundsen/Bellingshausen Sea sectors and Antarctic Peninsula in West Antarctica (Mouginot et al. 2019; Rignot et al. 2019, Pachauri et al. 2014).

Quantifying precipitation in Antarctica faces many unique challenges such as wind and other technical difficulties due to the harsh environment. In view of the logistic difficulty in obtaining reliable precipitation measurements, researchers have resorted to using other means, like satellite observations, reanalysis data sets and climate models (Malcom et al. 2018). But direct measurement of precipitation in Antarctic using ground-based instruments is important to validate the results from climate models, reanalyses and satellite observations. This study compares a variety of natural precipitation measurements in West Antarctica and these data of precipitation measurement can be used as a standard for validating precipitation observations from satellites and the long-term results obtained from climate models and reanalysis data sets.

Material and research methods.

In this work, we used data from instrumental observations of atmospheric precipitation in the re-

gion of Ukrainian Antarctic Vernadsky research base (65°14′44″S, 64°15′28″W) from 1998 to 2018, Russian Bellingshausen Antarctic station (62°11′55″S, 58°57′38″W) from 1998 to 2016 as well as Grytviken meteorological station (British Overseas Territory of South Georgia and South Sandwich Islands) (54°16′53.9″S, 36°30′30.4″W) for the period of station operation – from 1906 to 1981. All stations are located quite close and represent one geographical area – the northern part of West Antarctica (Fig. 1). The available series of instrumental observation data for precipitation at Antarctica are extremely limited, which is associated, first of all, with the late discovery of the continent, as well as with the limited logistics operations in the region even today. Therefore, the work used the available data on atmospheric precipitation, which are characterized by different periods and duration. However, these series overlap during certain periods of time, which allows the authors to draw conclusions regarding their synchronicity (similarity). As known, the Wolf number (also known as the International sunspot number, relative sunspot number, or Zürich number) is a quantity that measures the number of sunspots and groups of sunspots present on the surface of the Sun. In this work analysed the data from the World sunspot data center of the Royal Observatory of Belgium (Total…, 2020). El Niño–Southern Oscillation (ENSO) is an irregular periodic variation in winds and sea surface temperatures over the tropical eastern Pacific Ocean, affecting the climate of many regions of the world. The El Niño–Southern Oscillation is a single climate phenomenon that periodically fluctuates between three phases: Neutral, El Niño (warming phase of the sea temperature), and La Niña (cooling phase). For our calculations we used the Oceanic Niño Index, prepared by NOAA (Oceanic…, 2020). In the course of the work, well-known methods of mathematical and statistical analysis were used, implemented through the built-in functions of the software Microsoft Excel, Statistica from StatSoft Inc., Surfer from Golden Software LLC.

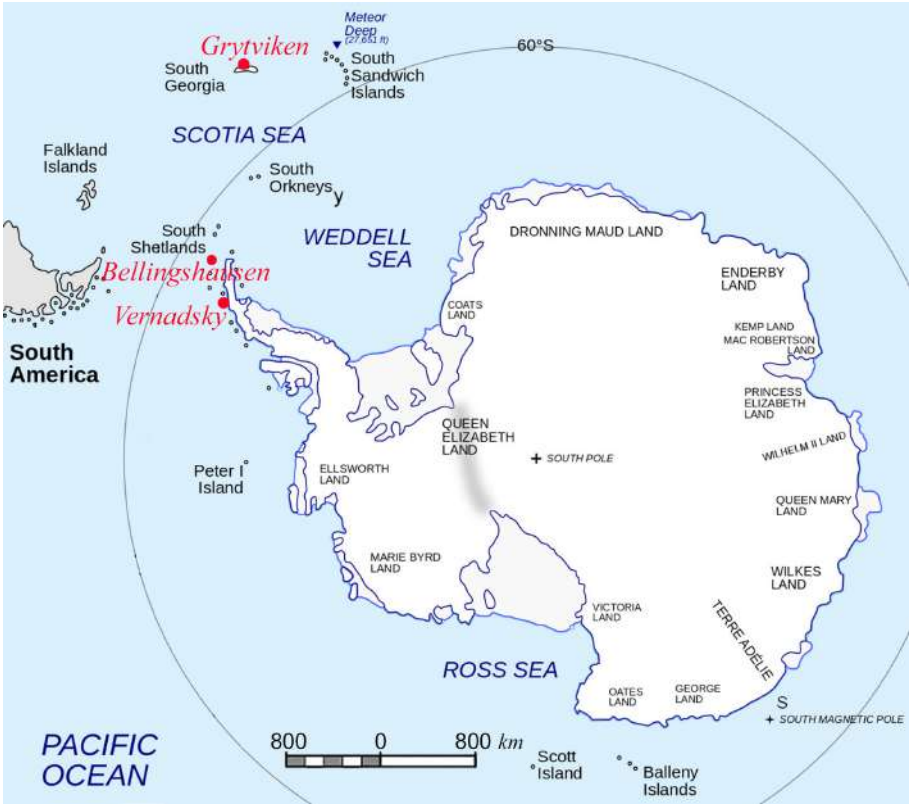

Fig. 1. Location of Vernadsky, Bellingshausen and Grytviken stations where the precipitation data was collected

To analyze the observational data in order to identify the components of the precipitation variability, a harmonic analysis technique was used, i. e. there were obtained trigonometric functions (harmonics) that were multiples of the series length. In this case, the harmonic equation has the following form:

$$G_k = A_{k*} \cos(\omega_{k*} t - \varphi_k), \qquad \omega_k = 2_* \pi / T_k, \qquad (1)$$

where k is the harmonic number, A_k – k^{th} harmonic amplitude, ω_k – k^{th} harmonic frequency, T_k – k^{th} harmonic period, φ_k – k^{th} harmonic phase, t – time (Brooks 1953).

Full expansion in a Fourier series involves the determination of harmonics, in the amount of $N/2$, where N is the series length. Harmonic characteristics are determined by finding the Fourier coefficients a_k and b_k

are given as: $a_k = 2 \div N * \sum_{i=1}^{N} [x_i * \sin(\omega_k * t_i)]$,

$$b_k = 2 \div N * \sum_{i=1}^{N} [x_i * \cos(\omega_k * t_i)] \quad (2)$$

With the aim of the Fourier coefficients calculation by the linear regression method in Microsoft Excel, the sines and cosines of harmonics for a certain date were calculated as used by (Blattner et al.1999):

$\sin_i = \sin(i \cdot \Omega \cdot date)$, $\cos_i = \cos(i \cdot \Omega \cdot date)$, (3)

where $\Omega = \frac{2\pi}{T}$; *date* – date corresponding to the source series value.

The linear regression equations were estimated using the coefficient of determination (Kd) R^2, which is the proportion of the variance in the dependent variable that is predictable from the independent variable(s). The significance of the coefficients was checked by using t-Student's criterion. The F-statistic was used to determine whether the observed relationship between the dependent and independent variables was random.

Results and discussions. The research area is characterized by unstable weather conditions, which are formed under the influence of marine air mass (Averyanov 1990; Sedunov 1991; Bogdanova *et al.* 2007; Klok 2010, 2013). With unstable weather, often in winter there is precipitation both in the liquid and in the solid phase, which affects the quality of precipitation measurement. In this work, we analyzed the data of monthly precipitation amounts presented in table 1.

Table 1. Precipitation observation data characteristics

Precipitation characteristics	Stations		
	Vernadsky	Bellingshausen	Grytviken
Observation period	01.1998–12.2018	01.1969–12.2016	01.1906–12.1981
Number of values	252	576	912
Average value, mm	48.6	58.1	123.1
Median, mm	43.0	54.3	113.4
Mode, mm	Multiple	47.4	98.3
Mode frequency	–	5	7
Maximum, mm	162.1	173.0	465.2
Maximum date	28.02.2005	31.07.1995	31.05.1970
Minimum, mm	1.9	11.7	10.8
Minimum date	31.12.2013	30.11.1978	30.09.1960
Standard deviation, mm	27.7	24.3	65.6
Annual maximum, mm	733.2	991.6	2626.7
Annual minimum, mm	379.9	471.8	888.0
Average annual value, mm	582.7	696.9	1477.3

The observational data obtained at the stations under study are shown in Fig. 1. Analyzing Table 1 and Fig. 2, it can be concluded that, firstly, the amount of precipitation at Vernadsky and Bellingshausen stations is approximately equal and, secondly, the distribution curves of precipitation at all three stations are very similar. And finally, the analysis of linear trends of the precipitation amount made it possible to establish that only for Grytviken station is a statistically significant positive trend of precipitation, while it is practically absent at Vernadsky and Bellingshausen stations, which is confirmed by the data from Table 2. Perhaps the reason for this is the shorter duration of the time series, limited here to 48 years (Bellingshausen) or even 21 years only (Vernadsky).

Table 2. Characteristics of the linear trends (cm/10 years) for precipitation data observation

Station	Observation period duration, year	Value	K_d	F
Vernadsky	21	-0.010	0.11	0.28
Bellingshausen	48	-0.014	0.06	0.32
Grytviken	75	0.015	2.38	22.20

Intra-annual variability. At the first stage, the characteristics of intra-annual component of the precipitation amount variability for above indicated stations were obtained. It should be noted that the obtained determination coefficient (in case on Vernadsky station, Kd = 19.0 %) indicated what part of the variability this model describes. At the same time, F-statistics show how trusted the results can be. In our case, F = 5.6, which is more than a given threshold value of 2 – for a significance level of 0.95 (Brooks, 1953). For Grytviken station these values are even higher (Kd = 19.0 %, F = 5.6) and for Bellingshausen stations Kd = 10.1 %, F = 6.4.

In the precipitation annual course, the intra-annual component of the precipitation amount variability at Vernadsky station is represented by 3 peaks – March, July and October, which is clearly seen from Fig. 3. The annual course of precipitation at Grytviken station, is also represented by three peaks – March, May and August, that is similar to Vernadsky station. At the same time, at Bellingshausen station, only 2 maximums are recorded (March and August), and the annual course of precipitation for this station is the most smooth.

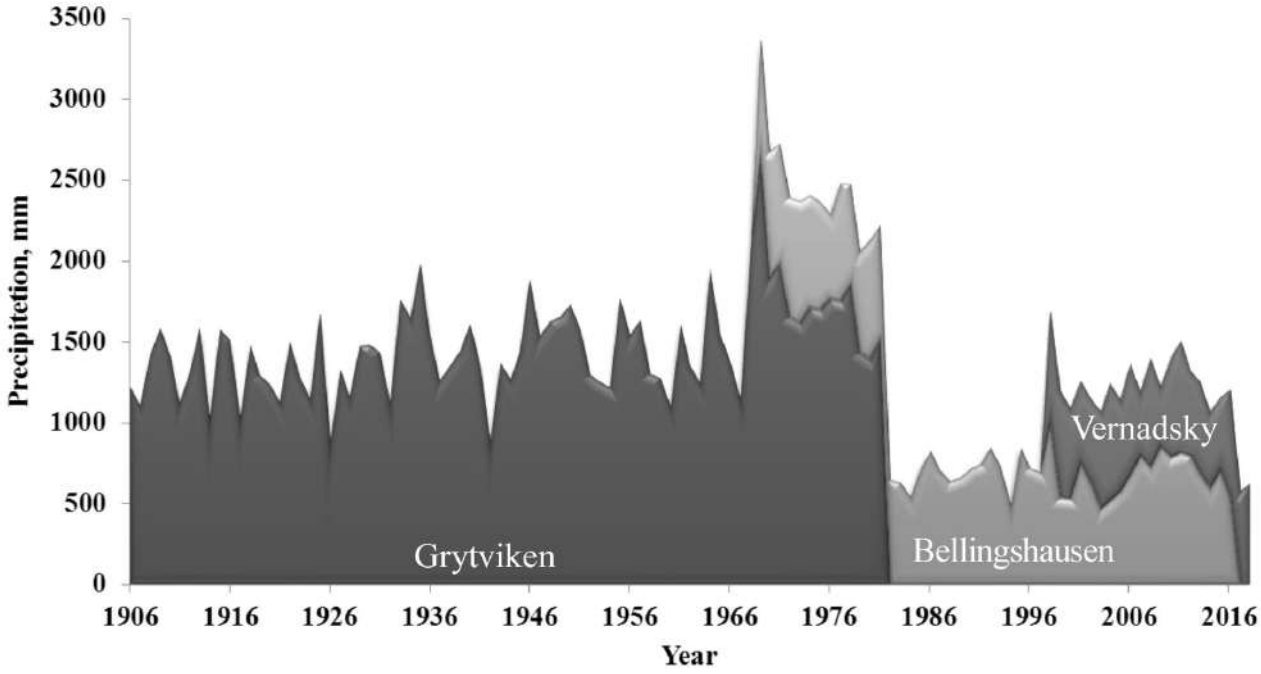

Fig. 2. Temporary distribution of annual precipitation at Vernadsky station during 1998–2018, Bellingshausen station during 1969–2016 and Grytviken station during 1906–1981.

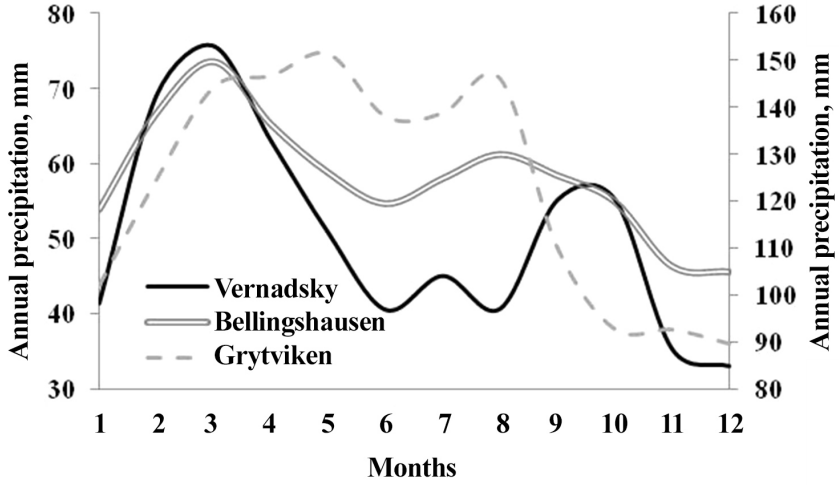

Fig. 3. The calculated curves of the seasonal variation of precipitation at the stations Vernadsky and Bellingshausen (left axis), and Grytviken (right axis).

In addition, the data analysis indicates a decrease of the intra-annual component over time for Vernadsky station. Also, its 4-year periodicity is well displayed; about the nature and possible reasons of it we will make an assumption in this work a little later. At the same time, data for other stations give different results (Fig. 4). For Grytviken station, there is practically no linear trend, while Bellingshausen station is characterized by an increase of the intra-annual component of precipitation variability over time. However, both stations have a 4-year periodicity, as at Vernadsky station.

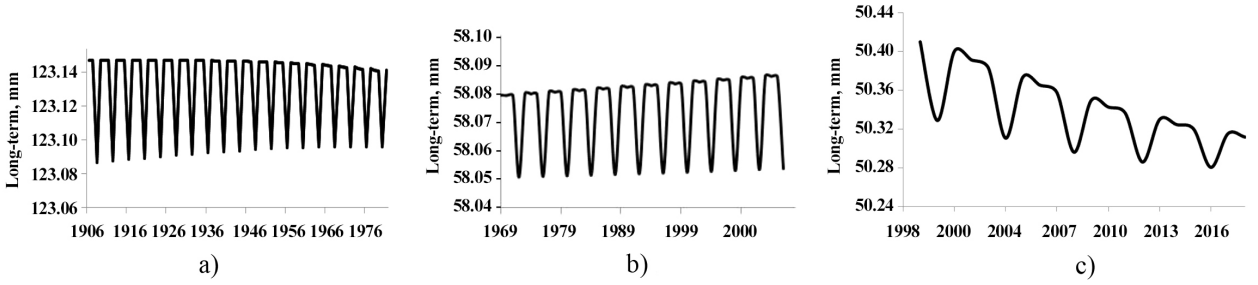

Fig. 4. Long-term dynamics of the precipitation intra-annual component according to the data from Grytviken (a), Bellingshausen (b) and Vernadsky (c) stations.

The analysis of the precipitation variability intra-annual component at the stations under researched can be summarized in the following table 3.

Table 3. Characteristics of the precipitation variability intra-annual component

Station	Period duration	K_d	F	Linear trend, mm/year		
				Value	K_d	F
Vernadsky	366.1	19.0	5.6	-0.010	57.70	25.96
Bellingshausen	365.1	10.1	6.4	-0.025	0.02	0.11
Grytviken	365.4	12.5	12.9	-0.013	0.11	0.08

The obtained amplitudes and phases of statistically significant harmonics of the seasonal variation of precipitation for the studied stations are shown in Fig. 5.

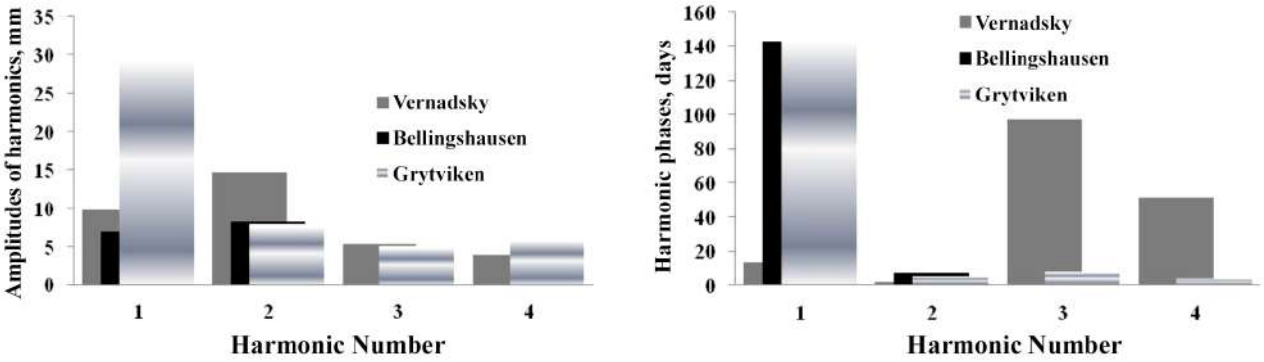

Fig. 5. Amplitudes and phases of harmonic of the intra-annual precipitation variability according to the data from Vernadsky (1998–2018), Grytviken (1906–1981) and Bellingshausen (1969–2016) stations.

The intra-annual component (annual course) of precipitation variability is described in works of other scientists, because it is not necessary to have long series of observations. But the results obtained by the authors are unique for the studied region, especially in terms of long-term changes. In the future, with their help it is possible to develop a scheme for long-term forecasting of weather conditions in the region.

Long-period variability.

The analysis of the long-period components of the precipitation variability was carried out on the residuals of the data obtained after the analysis of the intra-annual component. This made it possible to obtain not only the corresponding harmonics of the distribution, but also to distinguish the boundaries of periods (half periods). The characteristics of the precipitation variability over long periods according to the data from stations under study are shown on Fig. 6.

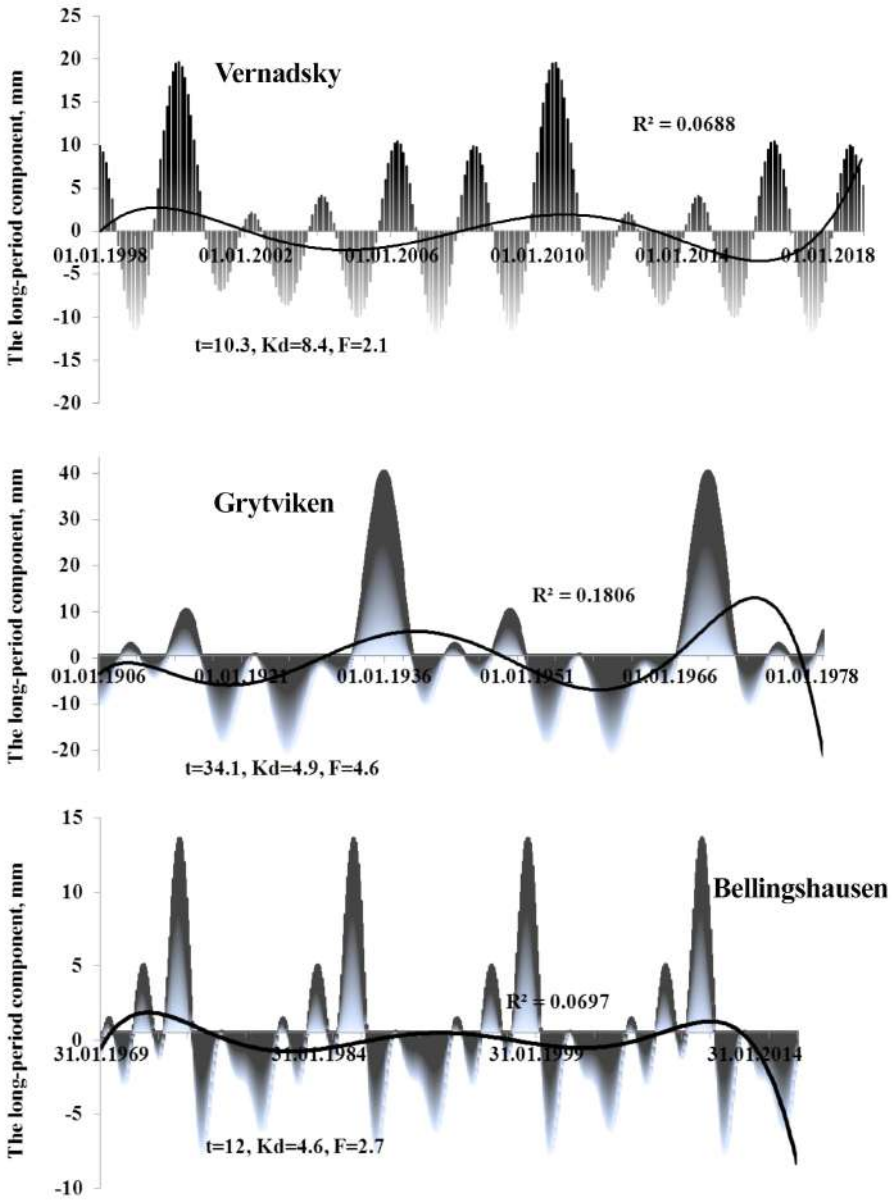

Fig. 6. The long-period component of precipitation variability according to observations at Vernadsky (1998–2018), Grytviken (1906–1981) and Bellingshausen (1969–2016) stations.

At Vernadsky station the period of variability is 10.3 years; Kd is 8.4 % with an F statistic is 2.1. According to the data from Grytviken station, the period of long-term variability here is 34.1 years; Kd is 4.9 % with an F-statistic of 4.6. And for Bellingshausen station the period of long-term variability is 12.0 years; Kd is 4.6 % with an F statistic is 2.7.

It is worth noting that in our case fairly good results were obtained, as for areas with difficult weather conditions, especially for Vernadsky research base. For Vernadsky station five statistically significant harmonics of the long-period precipitation variability were obtained, which are reflected in periods of 6.8, 2.4, 4.0, 5.1, and 5.3 years. At the same time for other station only 4 statistically significant harmonics were selected (fig. 7). In particular for Grytviken station four harmonics of the long-period precipitation variability were obtained, the periods of which are 4.2, 0.8, 1.7, and 8.9 years. For Bellingshausen station these periods are 1.5, 2, 2.8, and 0.2 years (for all stations the periods of fluctuations are listed because as decreasing of their strength).

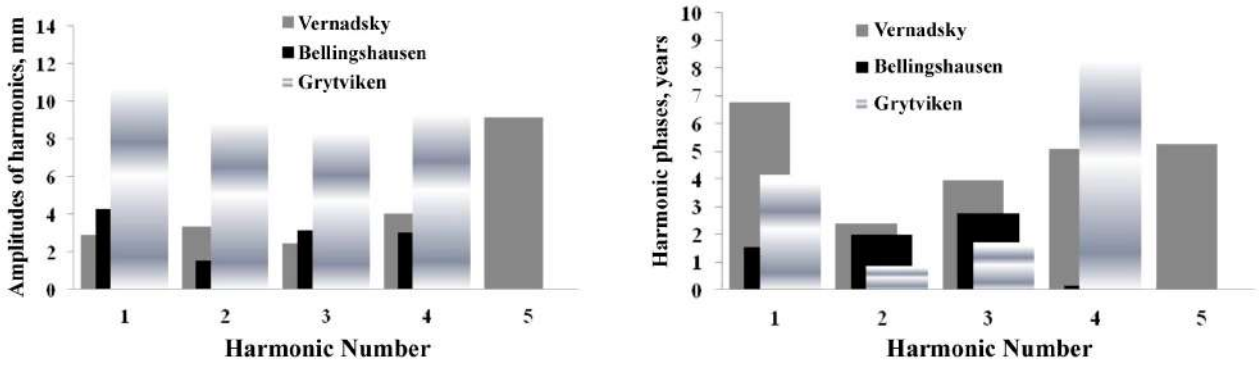

Fig. 7. Amplitudes and phases of harmonic of the long-period precipitation variability according to the data from Vernadsky (1998–2018), Grytviken (1906–1981) and Bellingshausen (1969–2016) stations.

To determine the boundaries of the variability periods, the 1st harmonic was built, the period of which Vernadsky station is 10.3 years (Fig. 8). The first harmonics for Grytviken station (34.1 years), as well as for Bellingshausen station (12 years) are also shown on Fig. 8.

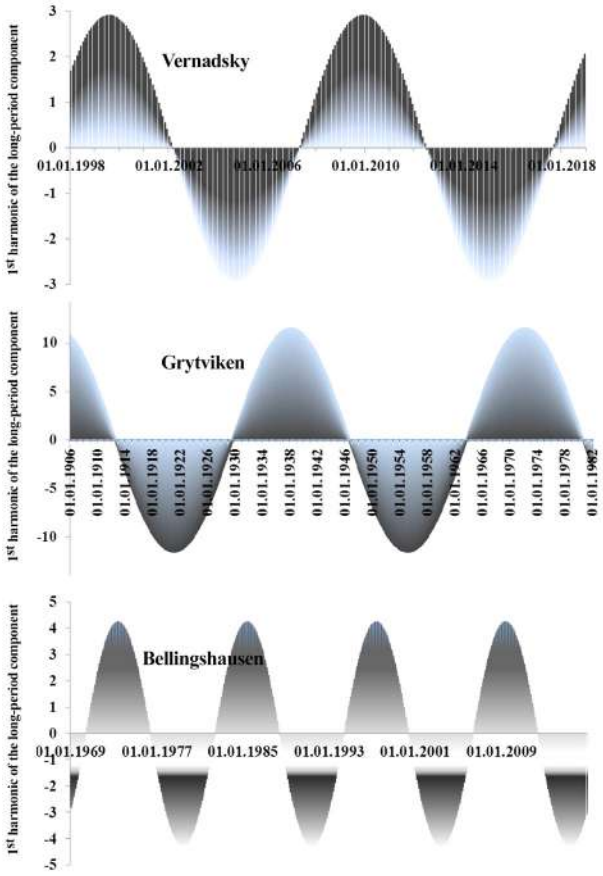

Fig. 8. General view of 1st harmonic of the long-period component of precipitation amount according to the data from Vernadsky (1998–2018), Grytviken (1906–1981) and Bellingshausen (1969–2016) stations.

The authors were able to describe the variability of precipitation in 29.4 % in the case of Vernadsky station, 15 % at Bellingshausen station and 19.8 % at Grytviken station. The authors were able to describe the variability of precipitation in 29.4 % in the case of Vernadsky station, 15 % at Bellingshausen station and 19.8 % at Grytviken station. We can assume that there are other, slower periods of oscillation, other than those obtained in this work.

Today, the main phases of solar activity are well known, which are about 11 years old. The long-period components of atmospheric precipitation variability obtained in the work for the stations under consideration (to 10.3, 12 and 34.1 years) are identical (close) to the mentioned phase of solar forcing. This allowed

drawing the preliminary conclusions about the influence of solar activity on the conditions for the formation of precipitation in the region under study. Despite the fact that the periods obtained by us are identical in duration to the periods of solar activity, it was not possible to obtain a clear correlation between them (fig. 9). So far, we have only used the direct pair correlation technique. Obviously, in the future, more detailed studies of this connection should be carried out using other mathematical methods.

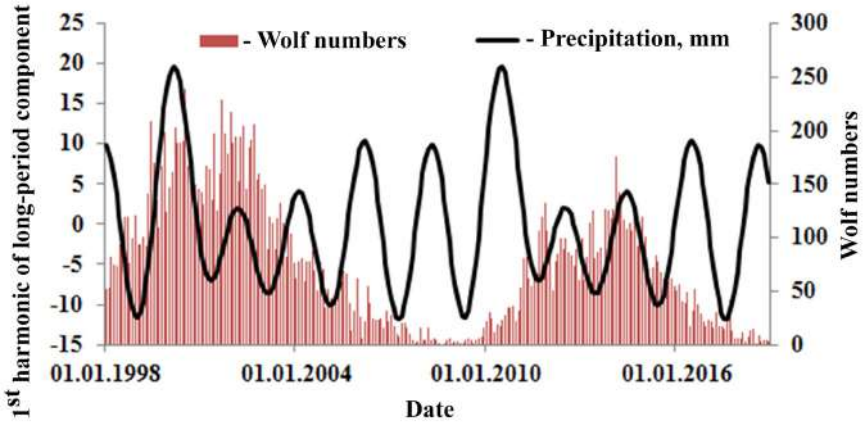

Fig. 9. The distribution of the long-period precipitation component (T = 10.3 years) according to observation from Vernadsky station relative to Wolf numbers for 1998–2018.

It is interesting to note that the performed analysis demonstrated the presence of a harmonic of about 4 years length at Vernadsky station as well as at Grüntwiken and Bellinghausen stations. With it that the intra-annual component of the precipitation amount variability can be associated, because in both cases it is such a periodicity that was found in the study of precipitation annual cource. We suggested that the 4-year periodicity is caused by El Niño/Southern Oscillation phenomenon (Oceanic… 2020), but their coordinated distribution showed on Fig. 10 does not confirm this.

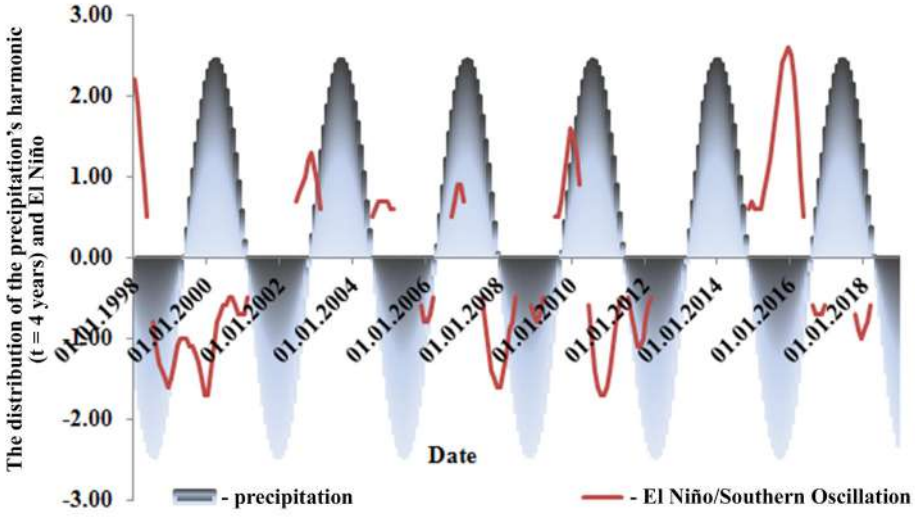

Fig. 10. The distribution of the precipitation's harmonic (t = 4 years) according to the data from Vernadsky and El Niño/Southern Oscillation coefficient for the period 1998–2018.

As in the case of the study of the influence of solar activity, it is necessary to expand the arsenal of methods in order to establish or refute this connection. It is necessary to look for other approaches to assessing the correlation, such as the lag method or sliding window correlation analysis.

Conclusions.

As a result of the study of monthly and annual precipitation amounts according to observations at Vernadsky and Grytviken stations, the characteristics of linear trends for these observations were obtained. In the case of Grytviken station the linear trend is turned out to be positive (0.015) and statistically significant

(Kd = 2.38, F = 22.2), while on Vernadsky and Bellingshausen stations its values are statistically insignificant and very small.

The intra-annual component of precipitation variability in this work covers 19 % of the total precipitation variability at Vernadsky station 12.5 % at Grytviken station and 10.1 % at Bellingshausen station. In the annual course, the component of precipitation variability is represented by 3 peaks – March, July and October, with a well-pronounced 4-year periodicity. However, data from Vernadsky station indicates a decrease of the seasonal component in time, while at Grytviken station the seasonal component is stable in time. In both cases, intra-annual variability was mainly determined by harmonics close to four-year ones, which suggests the certain role of the El Niño/ Southern oscillation phenomenon in its formation. The linear trend of this variability component in the case of Vernadsky station turned out to be –0.01 mm / year with Kd = 57.5 and F-statistics of 25.96 at the Grytviken station it was statistically insignificant.

The analysis of the long-period components of the precipitation variability was carried out on the residuals of the data obtained after the analysis of the intra-annual component. For the long-period component of precipitation variability at Vernadsky station, five statistically significant harmonics were obtained, which are reflected in periods of 6.8, 2.4, 4.0, 5.1, and 5.3 years. For the Grytviken station, 4 statistically significant harmonics were obtained, the periods of which are 4.2, 0.8, 1.7, 8.9 years, as well as 1.5, 2.0, 2.8, 0.2 years for Bellingshausen stations. The presence of harmonics the size of which is about 4 years, both at Vernadsky station and at Grytviken station, suggests that it is associated with the intra-annual component of variability of the precipitation amount (at both stations, such a periodicity was found when studying intra-annual variability). Comparing the distribution of this harmonic of precipitation amount and El Nino/Southern Oscillation coefficients, it can be assumed that the 4-year periodicity is caused by this phenomenon.

The commensurate periods of long-period oscillations obtained by us, equal to 10.3, 12.0 and 34.1 years, can serve as confirmation that the components of solar forcing variations are significantly involved in the formation of atmospheric precipitation in the studied region.

Climate models and observations are improving all the time and the reliability of predictions is likely to improve significantly over the next few years. In particular, new satellites and more detailed models are opening up new possibilities for understanding and predicting how precipitation cycles through the climate system. Considering the fact that the authors were able to describe the variability of precipitation in 29.4 % in the case of Vernadsky station, 15 % at Bellingshausen station and 19.8 % at Grytviken station, we can assume that there are other, slower periods of oscillation, other than those obtained in this work. The limited observational data used by us did not make it possible to conduct more advanced studies for today.

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Forecasts and demographic development of the population of Fergana Valley regions of Uzbekistan until 2040

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Abstract. The world's population is growing rapidly and today exceeds 7.8 billion people. World population growth is expected to slow down slowly in the future. A decade ago, the world's population increased by 1.24 percent; today it is 1.1 percent, an increase of 83 million a year. The world's population is expected to reach 8.6 billion by 2030. (UNFPA 2015). This creates a regional imbalance between population growth and the development of employment, production and social infrastructure. Information is needed on the creation of new jobs in the regions, for planning the construction of preschool institutions, schools, higher and secondary specialized educational institutions, how many children will be able to attend preschool institutions in the future, how many children will reach school age and how many children will be transfered to specialized secondary and higher education, how much the labor force will increase. The population of Uzbekistan is constantly growing. From 1991 to 2020, the country's population increased by 1.7 times. For comparison: during this period, the population of neighboring Kyrgyzstan increased by 1.3 times, the population of Kazakhstan – by 1.02 times, the population of Tajikistan – by 1.5 times, the population of Turkmenistan – by 1.4 times. During the years of independence in Uzbekistan, special attention was paid to demographic issues based on the population and the human factor, the principles of a healthy mother and a healthy child. The course of demographic processes changes in accordance with the natural, socio-economic geographical conditions of the regions (Tojieva Z. N. 2019). The Fergana Valley is the most densely populated region of Uzbekistan with a small territory, a large demographic load and the largest demographic potential (Abdullaev O. 2000). Land resources with limited, high demographic pressure require research aimed at identifying, predicting and preventing future adverse events specific to the development of demographic processes in the regions of the valley. The article makes a forecast for 2025–2040 and draws conclusions using the method of age shift of the population of regions, districts and cities of the Fergana Valley, demographic regions and gender and age composition.

Ключові слова: population, population forecast, demographic processes, age shift method, Fergana Valley regions, demographic regions.

Прогноз щодо демографічного розвитку населення регіонів Ферганської долини Узбекистану до 2040 року

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Анотація. Населення світу стрімко зростає і на сьогоднішній день перевищує 7,8 мільярдів осіб. Очікується, що у майбутньому зростання світового населення буде поступово уповільнюватися. Десять років тому населення світу збільшилося на 1,24 відсотка; сьогодні це 1,1 відсотка, що на 83 млн більше на рік. Очікується, що населення планети досягне 8,6 млрд до 2030 року (ЮНФПА 2015). Це створює регіональний дисбаланс між зростанням населення та розвитком зайнятості, виробництва та соціальної інфраструктури. Потрібна інформація про створення нових робочих місць у регіонах, для планування будівництва дошкільних закладів, шкіл, вищих та середніх спеціалізованих навчальних закладів, скільки дітей зможуть відвідувати дошкільні заклади в майбутньому, скільки дітей досягне шкільного віку і скільки дітей переведеться до середньої та вищої спеціальної освіти, наскільки збільшиться робоча сила. Населення Узбекистану постійно зростає. З 1991 по 2020 рік населення країни зросло в 1,7 рази. Для порівняння: за цей період населення сусіднього Киргизстану зросло в 1,3 рази, населення Казахстану – у 1,02 рази, населення Таджикистану – у 1,5 рази, населення Туркменістану – у 1,4 рази. За роки незалежності в Узбекистані особлива увага приділялася демографічним питанням, що ґрунтуються на кількості населення та людському факторі, принципах здорової матері та здорової дитини. Хід демографічних процесів змінюється відповідно до природних, соціально-економічних географічних умов регіонів (Тоджєва З. Н. 2019). Ферганська долина – найбільш густонаселений регіон Узбекистану з невеликою територією, великим демографічним навантаженням та найбільшим демографічним потенціалом (Абдуллаєв О. 2000). Земельні ресурси з обмеженим, високим демографічним тиском потребують досліджень, спрямованих на виявлення, прогнозування та запобігання майбутнім несприятливим подіям, характерним для розвитку демографічних

процесів у регіонах долини. У статті зроблено прогноз на 2025–2040 роки та зроблено висновки з використанням методу вікових змін населення регіонів, районів та міст Ферганської долини, демографічних регіонів та щодо статево-вікового складу.

Ключові слова: населення, прогноз населення, демографічні процеси, метод вікових змін, регіони Ферганської долини, демографія регіонів.

Introduction.

Demographic processes, population and dynamics, changes in its composition and territorial location determine its future status. Population forecasting plays an important role in the creation of new jobs, housing, kindergartens, schools, hospitals and other similar construction and material needs, as well as in the development, planning and territorial organization of production and infrastructure. In his address to the Oliy Majlis, President Shavkat Mirziyoyev said: "Fifth, employment and support for entrepreneurship will be in the spotlight. To this end, next year the vocational education system will be reformed on the basis of new approaches in accordance with the requirements of the labor market and international standards" (Address of the President of the Republic of Uzbekistan Shavkat Mirziyoyev to the Oliy Majlis // Xalq suzi, 2020. December 30. No 276 (7778)). It is important to predict changes in population, age and gender composition in the coming years.

The first demographic forecasts in Uzbekistan were developed under the leadership of M. K. Karakhanov in 1962–1980 (Karakhanov M., Kayumov A., 1984). In subsequent years, on these issues, R. N. Ubaydullaeva, O. B. Ata-Mirzaev (Ata-Mirzaev O.B., 1979), A. A. Kayumov, M. R. Burieva (Buryeva M. R., 2001), S. S. Zokirov, Z. N. Tojieva (Tojieva Z. N., 2002), H. H. Abduramanov (Abdurakhmonov K., Abduramanov H., 2011), R. B. Kadirov and others.

Research method.

Several methods are used in population forecasting, which vary in accuracy. Methods such as extrapolation, logical curves, age shifts are widely and effectively used (Valentey D. I., Kvasha A. Ya., 1989; EUROPEAN UNION, 2021; Isokova T., Khodjakulov H., 2004; Kayumov A. A., Yakubov O., 2011; Shryork, Henry S. 1976).

The following 3 formulas are often used to estimate the population using the extrapolation method:

1. The following formula is given in **the arithmetic method:**

$$P_n = P_0 (1+nr) \quad (1)$$

R in this formula is determined using the following formula:

$$r = \frac{(Pn - P0)}{n * P0} \quad (2)$$

2. The following formula is used in the **geometric method** of population forecasting:

$$P_n = P_o(1+r)^n \quad (3)$$

The value r in this formula is determined using the following formula:

$$r = \sqrt[n]{\frac{P0}{Pn} - 1} \quad (4)$$

3. In the exponential method, the following formula is given:

$$P_n = P_o p^{rn} \quad (5)$$

In this formula r:

r= In $(P_n/P_o)/n$ is determined using the formula;

here: P_n = Number of population in the forecast year;

P_0= Population in the current year;

n = difference between current year and forecasted year;

r = population growth rate;

In determining r, P_0 is the population in the initial year;

P_n- population in the current year;

P_{0-} is the population in the initial year;

n – is the difference between the starting year and the current year.

Forecasting the population using ***the age shift method***, taking into account changes in demographic processes, allows to draw clear conclusions. In this case, the future population is determined using the following formula:

$$L_x x P_x = L_{x+1} \quad (6)$$

Here: L_x -x is the number of people who can live up to the age; $P_x - x+1$ is the coefficient of probability to survive up; $L_{x+1} - x+1$ is the number of people who can live up.

Therefore, the population at each age (L_x) is shifted from one age (L_x) to another age $(L_x + 1)$ using the coefficient of probability (P_x) that each age can be achieved. In most cases, projections are made in the 5 or 10 year old age group.

Results and discussion.

In this study, forecasts for 2025, 2030, 2035 and 2040 were made at the district and city levels for the population of the country and the regions of the Fergana Valley by five-year age groups. It is based on indicators of population, birth and death rates in 2015–2020.

During the years of independence, Uzbekistan has had its own demographic development. Regions of the country have regional differences in terms of demographic development and population share. Territorial differences between regions are associated with their geographic location, natural conditions,

socio-economic development. Thus, a relatively high demographic potential is observed in the ancient Samarkand, Kashkadarya, Fergana and Andijan regions. On the contrary, most of its territory consists of deserts, and the lowest population growth rates are observed in the Syrdarya, Jizzakh and Navoi regions, which are the last among the regions of the country. This can be assessed as a significant inconvenience for the living conditions of the desert population. Consequently, the demographic potential of these regions is also low (Tojieva, 2010).

The unfavorable, difficult ecological situation for the population of the Lower Amu Darya also leads to a negative balance of population migration, the spread of diseases and illnesses. Despite the high birth rate and natural increase, the demographic potential of the region's population is declining.

The level of urbanization, high employment, the level of industrial development, as well as the location of the capital are the main factors of the low rates of natural population growth in the Tashkent region.

The level of urbanization, high employment, the level of industrial development, as well as the location of the capital are the main factors of the low rates of natural population growth in the Tashkent region.

In general, the current demographic processes in the country in the future will reduce the demographic potential of the population due to the unfavorable environmental situation in the Lower Amudarya region, unfavorable natural conditions in the Syrdarya, Jizzakh and Navoi regions. In addition, high fertility and low natural growth in the Tashkent region as a result of such factors as high urbanization and industrial development are important factors in reducing the demographic potential (Temirov, 2018).

In the central and southern regions of the country and in the Fergana Valley, the demographic potential will continue to grow. In other words, in the future, the country's population will "move" to the central, southern and eastern regions. The Fergana Valley is also expected to remain the most populous region in the country. In the first year of independence, 26.9 % of the country's population lived in the Fergana Valley. In recent years, the share of valley regions in the country's population has increased and amounted to 27.7 % in 2000 and 28.6 % in 2020.

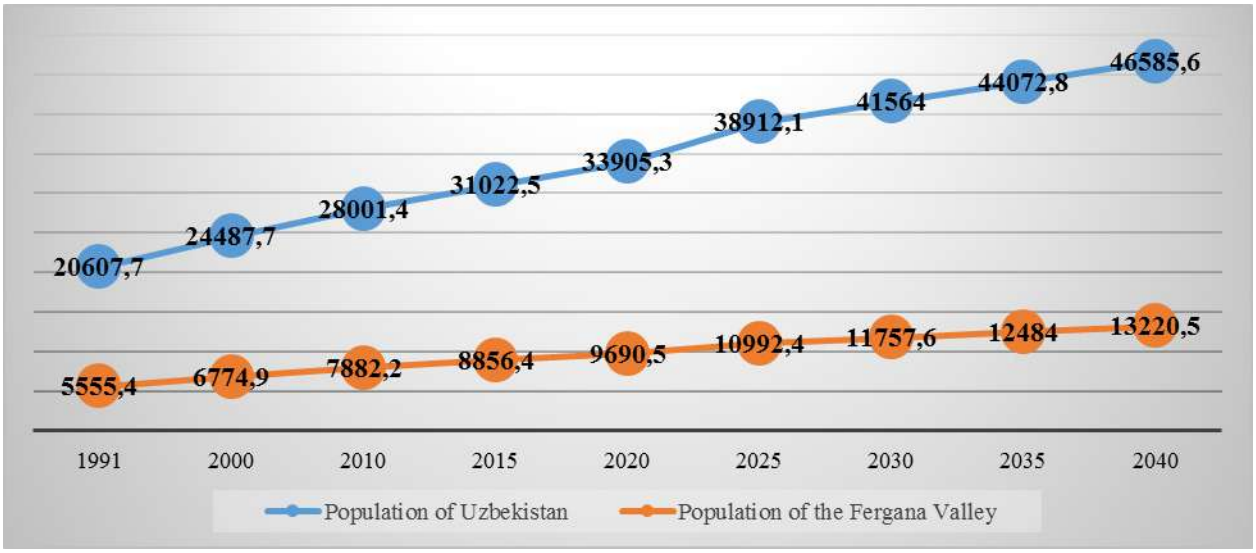

Fig. 1. Population forecast of the Republic of Uzbekistan and the Fergana Valley regions (thousand people)

According to the forecast, the valley regions' population is expected to be 28.3 % of the total country's population in 2030 and 28.4 % in 2040. Even in the forecast period, the population of the valley will hardly change in the country, and will also remain the region with the largest share in the country. (Fig. 1).

The natural increase in the urban population was lower than in the countryside. An important role is played by such factors as the complexity of the national and ethnic composition of the urban population, the high level of education of the population, the development of industrial production, and the level of employment of women in production. The share of urban population in Uzbekistan is expected to decline from 50.6 % to 48.4 % in 2020–2040. In the Fergana Valley, a decline is projected from 57.4 % to 56.4 % (Table 1). An important factor in this is the high level of urbanization of the valleys above the national average, a small difference in the natural growth of the urban and rural population.

During the forecast period, along with the high level of urbanization in the valley regions, there are also regional differences between the regions.

Table 1. Population forecast of the Republic of Uzbekistan and Fergana valley regions (2020–2040) (thousand people)

		1991	2000	2010	2015	2020	2025	2030	2035	2040
Republic of Uzbekistankasi	Total	**20607.7**	**24487.7**	**28001.4**	**31022.5**	**33905.3**	**38912.1**	**41564.0**	**44072.8**	**46585.6**
	City	8305.2	9165.5	14425.9	15748.0	17144.2	19413.0	20542.3	21557.0	22546.1
	Village	12302.5	15322.2	13575.5	15274.5	16761.1	19499.1	21022.7	22515.8	24039.5
Andijan region	Total	**1789.0**	**2186.2**	**2549.1**	**2857.3**	**3127.7**	**3447.5**	**3708.9**	**3960.2**	**4219.0**
	City	574.7	657.6	1358.4	1499.9	1633.9	1785.8	1905.3	2014.7	2125.7
	Village	1214.3	1528.6	1190.7	1357.4	1493.8	1661.7	1803.6	1945.5	2093.3
Namangan region	Total	**1551.8**	**1924.3**	**2258.5**	**2554.2**	**2810.8**	**3258.8**	**3493.5**	**3713.9**	**3933.6**
	City	591.3	722.6	1458.8	1618.8	1815.2	2098.0	2247.7	2377.4	2504.9
	Village	960.5	1201.7	799.7	935.4	9956.6	1160.8	1245.8	1336.5	1428.7
Fergana region	Total	**2214.6**	**2664.4**	**3074.6**	**3444.9**	**3752.0**	**4286.2**	**4555.1**	**4809.9**	**5068.0**
	City	686.2	776.1	1802.6	1965.9	2117.6	2406.0	2555.1	2693.6	2827.8
	Village	1528.4	1888.3	1272.0	1479.0	1634.4	1880.2	2000.0	2116.3	2240.2
Fergana Valley	Total	**5555.4**	**6774.9**	**7882.2**	**8856.4**	**9690.5**	**10992.4**	**11757.6**	**12484.0**	**13220.5**
	City	1883.3	2156.2	4619.7	5084.7	5566.7	6289.7	6708.1	7085.7	7458.4
	Village	3672.1	4618.7	3262.5	3771.7	4123.8	4702.7	5049.5	5398.3	5762.1
The weight of the Fergana region	Total	**26.9**	**27.7**	**28.1**	**28.5**	**28.6**	**28.4**	**28.3**	**28.3**	**28.4**

The table was prepared by the author based on the data of the Statistical Committee of the Republic of Uzbekistan.

In particular, Andijan region, which has the lowest level of urbanization among the valley regions, will decrease from 52.2 % to 50.4 % in 2020–2040, and Namangan region, which has the highest level of urbanization, will decrease from 64.6 % up to 63.7 %. The main factor is the decrease in urbanization in the Andijan region by 1.8 %, the high natural growth of the rural population, while in the Namangan region there is no significant difference between the high natural growth of the urban population and the natural growth of the rural population. In the Fergana region, a decrease in the level of urbanization is expected from 56.4 % to 55.8 % in the forecast period. Natural population growth in the Fergana region is low compared to neighboring regions.

Regional differences in the rates of natural population growth in the valleys will lead to a decrease in the proportion of the population in the Andijan and Fergana regions and an increase in the proportion of the population in the Namangan region, which has a high population growth rate.

The growth of the population of the Fergana Valley leads to a change in its sex and age composition. In particular, low fertility leads to a decrease in the proportion of young people in the population, and low mortality and, accordingly, an increase in life expectancy leads to an increase in the proportion of older people in the age group. In the forecast years, the share of the population of the valleys at the age of 0–15 is expected to decrease, i. e. to working age from 29 % to 25.5 % (Fig. 2).

In addition, low mortality and an increase in life expectancy will lead to an increase in the proportion of retirement age from 10 % to 16.9 %. The share of the working-age population decreased from 60.6 % to 57.6 %. Such changes in the age structure of the population mean that in the future there will be an increase in the demographic pressure of children and the elderly per 100 people of working age. According to the analysis, for every 100 people of working age in 2020, there were 47.9 children under the age of 15 and 17.1 people of retirement age with a total demographic pressure of 65.0, while in 2030 this figure is going to be 49.6 and 25 people, respectively, the total amount is in 2040 is 74.7, 44.3 and 29.3, 73.6. Demographic pressures in the valleys are expected to intensify in the future, and the ratio between children under 15 and retirement age will also change. This is important when planning future material production.

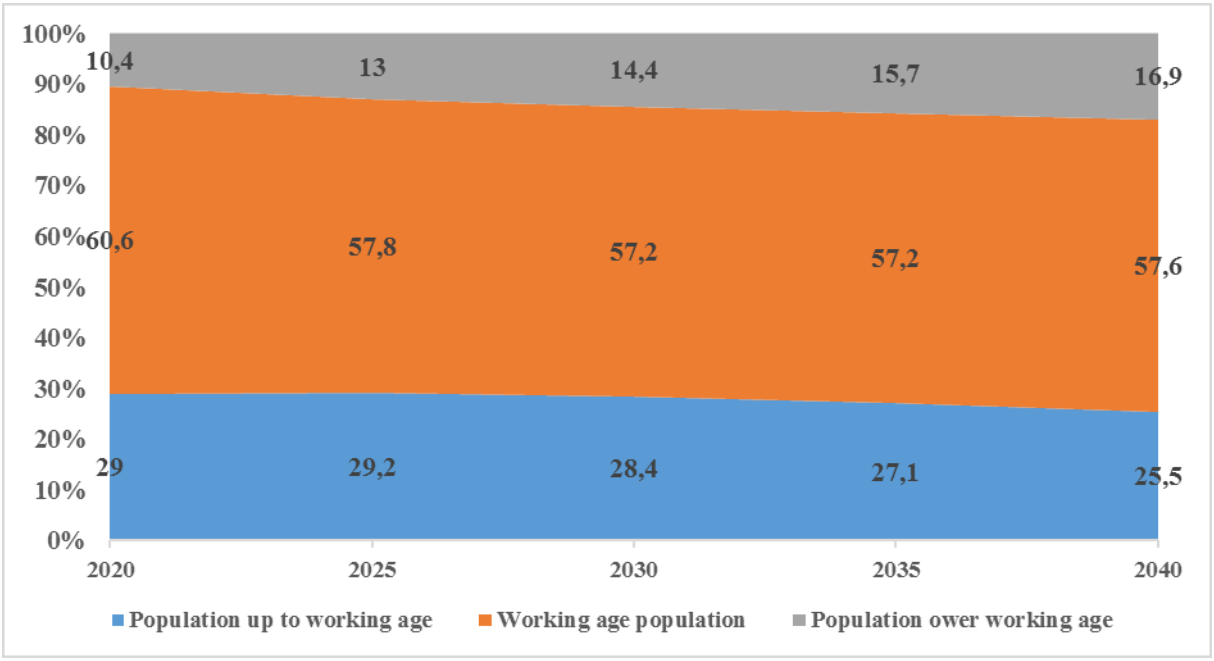

Fig. 2. Forecast of age changes in the population of the Fergana Valley NOTE in grey " over working age ' not "ower "

Demographic pressures also have regional differences between the regions of the valley, where the development of demographic processes is different (Table 2).

Table 2. Growth of demographic pressure in the Fergana Valley due to the working age population

Regions of the Fergana Valley	2020				2030				2040			
	Andijon	Namangan	Fergana	Regions of the Fergana Valley	Andijon	Namangan	Fergana	Regions of the Fergana Valley	Andijon	Namangan	Fergana	Regions of the Fergana Valley
Young people of 0–15 years	49.0	48.4	46.8	47.9	51.6	50.3	47.3	49.6	46.1	44.4	42.8	44.3
Retirement age	17.1	15.9	18.0	17.1	24.3	24.0	26.7	25.1	28.4	28.2	30.9	29.3
Total	66.0	64.3	64.7	65.0	75.9	74.3	74.0	74.7	74.5	72.7	73.7	73.6

The table was calculated by the author on the basis of data from the Statistics Committee of the Republic of Uzbekistan

In particular, Andijan region is characterized by high demographic pressure in the valley. Factors such as high birth rates in rural areas, high population density, negative migration balance can be considered as important factors in the high demographic pressure in Andijan region. In Andijan region, the demographic pressure of children under 15 years of age in 2020–2040 is high, while in Fergana region, where the birth rate is low, the demographic pressure of the population of retirement age is high.

The gender composition of the population also plays an important role, taking into account the future development of demographic processes. The sex composition of the Fergana Valley is expected to be higher in the future. According to the analysis, in 2020, men made up 50.6 percent of the total population in the valley regions, up from 51.8 percent in 2030 and 51.4 percent in 2040. In 2020, most men will be under the age of 44, and after 2030, this figure is expected to reach 64. The key factor here is the reduction in the mortality rate of men in different age groups. Accordingly, the gap between the average life expectancy of men and women is narrowing. The decline in the proportion of women in the total population, especially in the 15 to 49 age group, also affects marriage and fertility. In the Fergana Valley, the proportion of women of childbearing age in 2020 was 26.3 %, while according to the analysis, this figure is expected to be 23.7 % and 23.4 % in 2030. In

the Fergana Valley, the proportion of women aged 15–49 in the total population will decrease, as well as the proportion of women in the total population, which in the future will lead to a decrease in the birth rate and natural population growth.

The steady growth of the population of the Fergana Valley, the growth of population density in the region leads to the aggravation of a number of related social problems. The Fergana Valley is one of the most densely populated regions of the country. In 2020, the population density in Uzbekistan will be every km.sq. On average, 523.0 people in the Fergana Valley, 727.4 people in the Andijan region, 377.8 people in the Namangan region and 555.0 people in the Fergana region. In the future, as the population of the regions of the valley increases, its density will also increase.

Natural and climatic conditions in the distribution of the population are a key factor in the emergence of territorial differences. The distribution of the population of the valley regions is also influenced by natural and climatic conditions, as well as the state of urban planning and socio-economic development of regions and other factors. This led to differences in the location of the regions of the valley, its density and the demographic potential of the regions. In the regions of the Fergana Valley, the territorial distribution of the population was divided into demographic regions based on regional differences in demographic processes (Temirov, 2020) (Fig.3.). The course of demographic processes in these demographic regions has led to differences and fluctuations in population and demographic potential (Table 3).

Table 3. Population and share change in the demographic regions of the Fergana Valley (2020–2040)

Demographic regions	Area	2020	2025	2030	2035	2040
Northern Fergana	15.4 2.85	22.7 2201451	23.3 2559710	23.4 2749033	23.5 2931466	23.6 3114441
Central Fergana	9.6 1.79	3.8 366683	3.8 416740	3.8 447330	3.8 476551	3.8 506350
North-Western Fergana	20.7 3.85	5.0 483699	5.0 554193	5.0 588493	4.9 616365	4.9 643922
South-Western Fergana	19.7 3.66	20.2 1955012	20.4 2245010	20.4 2393836	20.3 2540397	20.4 2691137
Eastern Fergana	20.0 3.70	30.9 2996697	30.0 3302835	30.2 3553576	30.4 3794730	30.6 4042671
Southern Fergana	14.5 2.70	17.4 1687018	17.4 1913938	17.2 2025329	17.0 2124493	16.8 2222001
The total for the valley regions	100 18.5	100 9690560	100 10992425	100 11757598	100 12484002	100 13220521

The table was by the author on the basis of the data from the Statistics Committee of the Republic of Uzbekistan by the method of age.

Note: The proportion of the population in fractions and the number of people in denominators

The predominance of the Adyr region in the demographic region of the Northern Fergana is favorable for horticulture, viticulture and animal husbandry, and the demographic region has favorable natural and climatic conditions for the accommodation and residence of the population. This demographic region accounts for 15.4 % of the valley's area and 22.7 % of the population. Fertility and natural increase in the demographic region of northern Fergana are high with the valley's population projected to reach 23.4 percent in 2030 and 23.7 percent in 2040.

The demographic region of the North-Western Fergana is sparsely populated due to the presence of mountains and hills, which are inconvenient for the population and agriculture. This demographic region accounts for 9.6 % of the territory of the Fergana Valley and only 5.0 % of the population. The unfavorable relief conditions in the region have led to low fertility, mortality and natural increase. The share of the population of the demographic region will decrease slightly in the future.

The demographic region of Central Fergana received new development and settlement in the second half of the last century. Due to the fact that the demographic region consists mainly of desert and semi-desert plains, the population is small. Although, the valleys make up about 10 percent of the province's land area, they make up 3.8 percent of the population. In the projected years, the proportion of the population of this demographic region will not change.

The demographic region of South-Western Fergana, including the western regions of the Fergana region, is located mainly in mountainous, foothill and lowland areas. The demographic region has territorial differences in the location of the population and demographic

processes. Population density, birth rate and natural increase are increasing from the west to the east of the region. This demographic region accounts for 19.7 % of the valley's area and 20.2 % of the population. Even in the forecast period, there are almost no changes in the population of the demographic region.

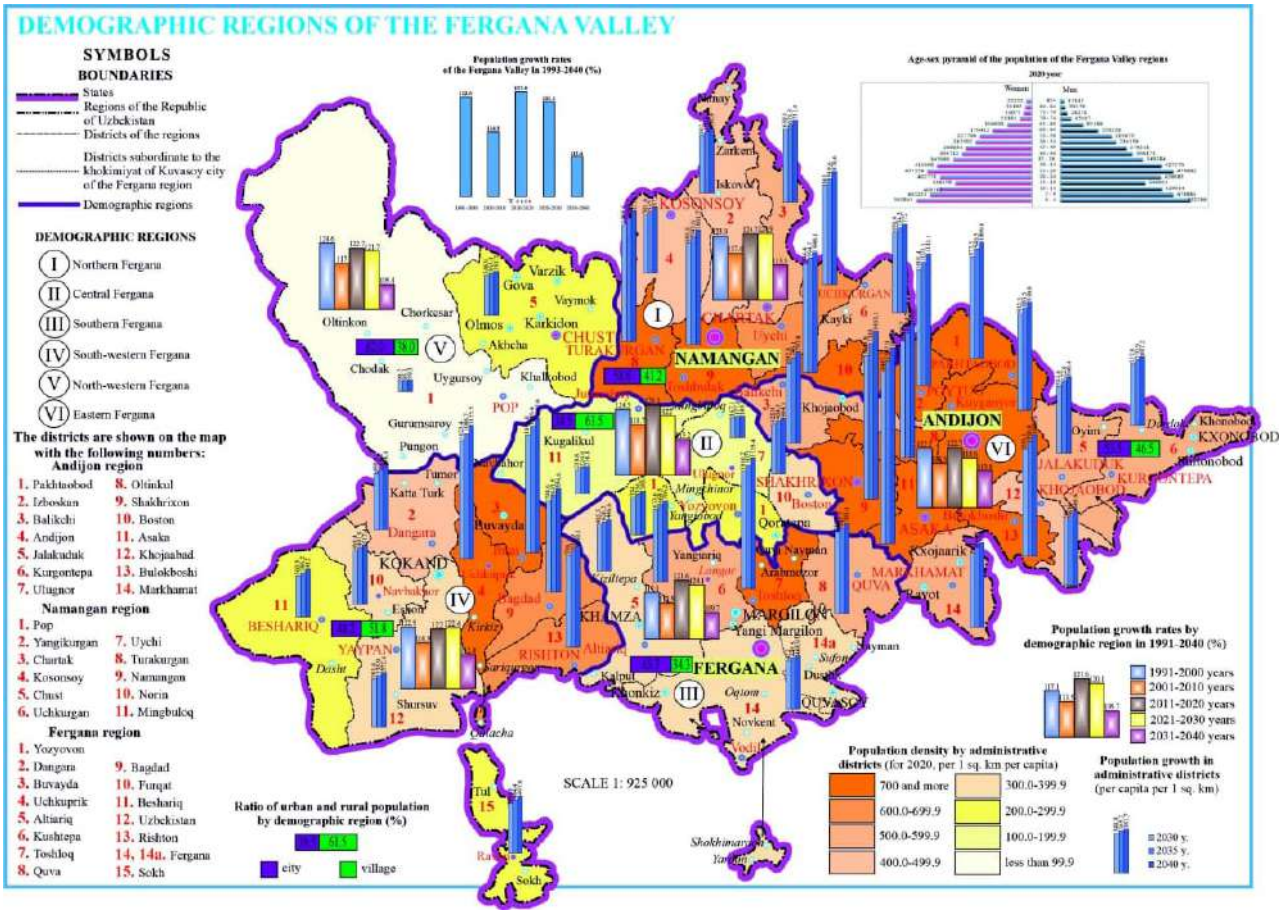

Fig. 3. Demographic regions of the Fergana Valley

Favorable natural and climatic conditions, favorable relief (hills) for the development of agriculture, good climate and good water resources are important factors of high population density in the demographic region of Eastern Fergana. Thus, this demographic region accounts for about 31 percent. In the future, the extreme population size and density will have an impact on population growth, and the region share is projected to decline.

The high level of urbanization in the demographic region of southern Fergana influenced the demographic processes. Low fertility and natural growth in the future will lead to a decrease in the population of the demographic region. According to forecasts, in 2020, 17.4 percent of the valley's population will live in the region, in 2030 the population will decline to 17.2 percent, and in 2040 – to 16.8 percent.

It is known that the birth rate and natural increase in cities is lower than in rural areas. In the demographic regions of the Fergana Valley, it is easy to feel the influence of the central and large cities of the regions on demographic processes (Table 4).

Table 4. Population growth rate in the demographic regions of the Fergana Valley

Demographic regions	Level of urbanization	**1991–2000**	**2000–2010**	**2010–2020**	**2020–2030**	**2030–2040**
South-western Fergana	48.2	122.9	116.9	122.0	122.4	112.4
Southern Fergana	65.7	117.1	113.5	121.6	120.1	109.7
Eastern Fergana	53.5	122.2	116.5	122.7	118.6	113.8
Northern Fergana	58.8	123.9	117.4	124.7	124.9	113.3
North-western Fergana	62.0	124.6	117.0	122.7	121.7	109.4
Central Fergana	38.5	124.5	118.7	126.1	122.0	113.2
The total of the valley regions	57.4	122.0	116.3	122.9	121.3	112.4

The table was developed by the author on the basis of data from the Statistics Committee of the Republic of Uzbekistan by the method of age

In the Fergana Valley, population growth was 122 percent in 1991–2000 and declined over the next decade. The population growth rate in 2000–2010 was 116.3 %, and the decline in this period is due to the low population growth rate in 2030–2040, i. e. periodic fluctuations. Also, the level of urbanization of demographic regions affects the rate of population growth, creating a peculiar geodemographic wave.

The Southern Demographic Region has the highest urbanization and the lowest population growth rates. In 2000–2010, a decline in population growth was observed in the Eastern and South-Western demographic regions in the east and west of the southern demographic region. High population growth rates in 1991–2000 are an important factor behind high growth rates in 2010–2020. The greatest growth in this decade was observed in the demographic regions of Central and Northern Fergana. The lowest growth is expected in East Fergana in 2020–2030, and the lowest population growth is expected in North Fergana and North-West Fergana in 2030–2040. In general, in the demographic valley regions, it is expected that geodemographic waves will begin in South Fergana and end in Northern and North-Western Fergana.

Conclusion.

– According to forecasts, in the future the population of the Fergana Valley will grow and Fergana Valley will remain one of the largest regions of the country. The central and large cities of the Fergana Valley play an important role in the demographic processes of the regions. With the distance from large cities, the population density and the level of urbanization decrease and demographic processes change. Territorial differences in the natural rates of population growth in the valleys will lead to a further decrease in the population of the Andijan and Fergana regions and an increase in the population of the Namangan region, which has a high population growth rate;

– Among the demographic regions there is a possibility of territorial organization of the population in the Central Fergana demographic region. It is advisable to carry out “internal migration” from regions with a heavy demographic burden by creating new highly profitable jobs in the central demographic region;

– Future population growth in the valley regions will lead to changes in both its age and sexual composition. The low birth rate leads to a decrease in the proportion of young people in the age structure of the population, while the low mortality rate and, consequently, the increase in the life expectancy of the population leads to an increase in the proportion of the elderly. The increase of the share of the elderly people, their biological aging leads to an increase in the burden on health care. It requires further development of sanatorium activities for the treatment and rehabilitation of the elderly;

– A decrease in the proportion of the population aged 15–59 leads to an increase in demographic pressure per 100 people of working age. This situation creates the need to create new jobs, increase employment, income and livelihoods through the placement in the future of industries of international importance;

– Periodic fluctuations in the birth rate and natural population growth in the valleys, the demographic urbanization of the region, the level of employment and education and other factors affect the rate of population growth and create a unique geodemographic wave. In the demographic regions of the Fergana Valley, geodemographic waves are expected to begin in the southern part of Fergana and end in Northern and North-Western Fergana. When planning the socio-economic development of the Fergana Valley, creating new jobs and decent living conditions for the population, it is advisable to take into account the development of demographic processes in demographic regions.

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Inclusive development of social entrepreneurship in nature management

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Abstact. Social entrepreneurship development in Ukraine is a priority guideline based on the creation and improvement of government policy on ecosystem orientation and inclusion, which provides public access to tourism and natural resources. The main component of inclusive development of social entrepreneurship emphasizes the basic principles of its existence, such as the ability to achieve one's own goals, despite the economic effect of one's activities. In the quantitative comparative analysis and need to reach economic indicators, the main factors are determined by the idea of inclusive development in nature management, as a field of activity in which not only the state but also multidisciplinary international organizations invest. The aim of the article is to identify opportunities for inclusive nature management development in social entrepreneurship in Ukraine by summarizing the existing practice of using indices and identifying indicators that will correspond to inclusive nature management parameters. Determining the position and directions of social entrepreneurship development in Ukraine was determined using an index approach, which, in contrast to others, allows one to identify indicators that characterize the sphere of development on economic and environmental influence of the country on the basis of inclusivity. The analysis of international rating assessments and Ukraine's place in them requires a rethinking of existing approaches to the search for economically feasible ways to improve socio-economic and environmental indicators and their rating positions. The method of multi-indicator immersion is used in the article to identify the main indicators of economic, inclusive growth and social components, which are due to the experience in nature management and characterize the development of social entrepreneurship. The calculations of the Inclusive Development Index of Social Entrepreneurship in Ukraine as a consolidated index according to the geometric formula, which comprised synthetic indicators of the human capital index to outline the inclusive range of components, brand index and index of environmental indicators, proved that today the ecological state of environment and health of the population have a significant negative impact on economic growth and welfare of the population.

Ключові слова: inclusive development, social entrepreneurship, nature management, index approach.

Інклюзивний розвиток соціального підприємництва в природокористуванні

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Анотація. Розвиток соціального підприємництва в Україні виступає першочерговим орієнтиром розвитку соціальних підприємств на основі створення та удосконалення політики уряду щодо екосистемної орієнтації та інклюзії, яка передбачає суспільний доступ до туристичних та природних ресурсів. При цьому основна складова інклюзивного розвитку соціального підприємництва підкреслює основні принципи його існування, такі як здатність реалізації власних цілей, незважаючи на економічний ефект від своєї діяльності. При кількісному порівняльному аналізі та необхідності виходу на економічні показники основні фактори визначаються ідеєю інклюзивного розвитку в природокористуванні, як тої сфери діяльності, в яку інвестує не лише держава, а й багатопрофільні міжнародні організації. Метою статті є ідентифікація можливостей розвитку інклюзивного природокористування в соціальному підприємництві в Україні шляхом узагальнення існуючої практики застосування індексів та виокремлення індикаторів, які будуть відповідати параметрам інклюзивності в природокористуванні. Визначення позиції та напрямів розвитку соціального підприємництва в Україні було визначено за допомогою індексного підходу, який на відміну від інших дозволяє виокремити індикатори, які характеризують сферу впливу на економіко-екологічний розвиток країни на

засадах інклюзивності. Аналіз міжнародних рейтингових оцінок та місце в них України потребує переосмислення існуючих підходів до пошуку економічно доцільних напрямів підвищення соціо-економіко-екологічних показників та своїх рейтингових позицій. В статті методом мультиіндекаторної імерсії виявлено основні індикатори економічного зростання, інклюзивного зростання та соціальних складових, що обумовлені досвід у природокористуванні якими характеризується розвиток соціального підприємництва. Проведено розрахунки Індексу інклюзивного розвитку соціального підприємництва в Україні як зведеного індексу за формулою середньо геометричного, який включив в себе синтетичні індикатори індексу людського капіталу для окреслення інклюзивного кола складових, індексу бренду та індексу екологічних показників, який довів, що сьогодні екологічний стан довкілля та здоров'я населення оказують значний негативний вплив на економічне зростання держави та добробут населення.

Ключові слова: інклюзивний розвиток, соціальне підприємництво, природокористування, індексний підхід.

Introduction.

Inclusive development of social entrepreneurship is a fairly new vector of today. This is due to the contradictions that arise between inclusion and social entrepreneurship in nature management. Thus, if inclusion provides public access to tourism and natural resources, which is guaranteed by the state, the development of social entrepreneurship is based primarily on making a profit from its activities for its further redistribution to social needs.

Social entrepreneurship shows how developed in the country are the institutional environment and business support which are based on the principles of sustainability and inclusivity. The index approach is the most convenient way to perform calculations, while analyzing many disparate indicators and elements and combining them into one set (aggregate).

To study individual indicators an index approach was chosen with which it will be possible to determine the current state of the inclusive economy in Ukraine and identify opportunities for its development. Theoretical index analysis makes it possible to compare economic phenomena between the compared situations and elements of the system and carry out analysis of qualitative differences between individual factors of the system.

Strategic management of economic system development (Seleznova, Boiko, Bondar, 2020) provides the relationship of strategic objectives with indicators of current development. Thus, in this study it is necessary to identify synthetic indicators based on the generalization of indicators inherent in the inclusive development of social entrepreneurship in nature management. The result indicators of the general change generated by complex economic phenomena are broken down into the individual components of this phenomenon or factors influencing it. So, it is advisable to dwell in more detail on the indices and their components used in international practice.

The aim of the article is to identify opportunities for the inclusive development of nature management in social entrepreneurship in Ukraine by summarizing the existing practice of using indices and identifying indicators that will show the parameters of nature management inclusiveness.

Problem statement.

According to the indicative goals and objectives of the National Civil Society Development Ukraine Strategy for the years 2021–2026, social entrepreneurship is defined as a springboard for the key vectors of social awareness development of the community and the key areas of inclusion and sustainability in the business environment.

There are a number of documents developed on international achievements in the progress of social entrepreneurship in Ukraine (Global Innovation Index 2020) which state that the primary guideline of amplification of social enterprises is the creation and improvement of government policy on ecosystem orientation. At the same time, foreign experts have developed two criteria groups for the activities of social enterprises divided into economic and social, namely: the creation of entrepreneurship on a voluntary basis with a minimum number of paid employees, the volunteering being aimed at profit, a significant part of which will be distributed to the needs of society. Areas of activity and decisions are regulated by voting, regardless of the capital contributed by a member of the enterprise.

Today, the activities of social startups are a new direction of profit, competitive advantages of business development with a focus on social and inclusive goals. Ukrainian researchers (The Inclusive Development Index 2018) have proved that the main vectors of social entrepreneurship development are as follows:

– first of all, it is the ideology of doing business according to international recommendations;

– accessibility to its products of all segments of the population and obtaining commercial benefits from activities;

– environmentally oriented component in conducting commercial activities.

The legislation prescribes such activities and has many competitive advantages related to taxes, fees, etc. However, there are no clearly defined normative and methodological recommendations for calculating the level of social entrepreneurship development in Ukraine. Therefore, the purpose of this article is to scientifically generalize index approaches to calculating the level of industry development in the country and to distinguish from their composition indicators that would

clearly characterize the state of social entrepreneurship development.

Material and Methods.

The definition of the theoretical basis was carried out using the method of theoretical generalization to identify the main indicators in international indices that characterize social entrepreneurship development. To identify index indicators of social entrepreneurship progress, we used the multi-indicator immersion method to identify the indicators of economic growth, inclusive growth and social components, which are due to experience in nature management.

The characteristic indicators outlining the formation of social entrepreneurship in the country are indices. Thus, the Inclusive Development Index (INCI) is an annual assessment of economic progress that does not use GDP. The index includes: components of economic development, gender equity and equality, inclusivity in financial and environmental governance. The latest data on the Inclusive Development Index show that Ukraine takes 49th place in the ranking, having lost 6.8 % over the past 5 years.

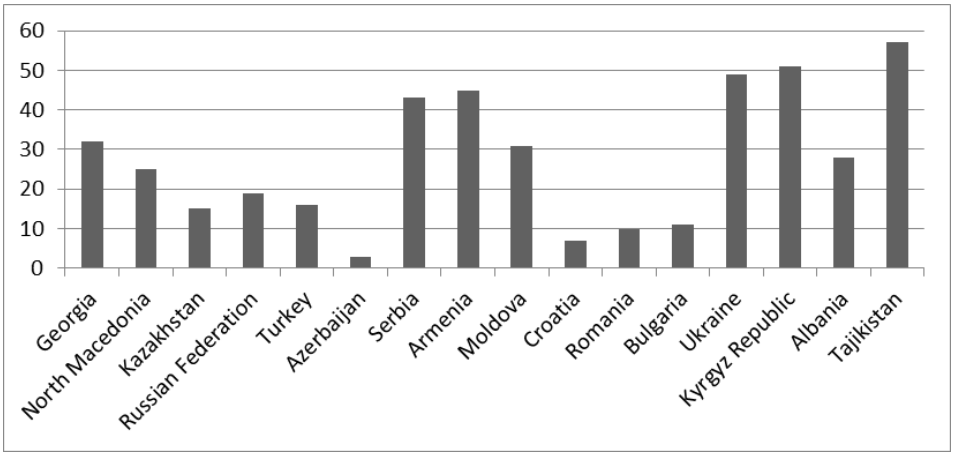

Fig. 1. The Inclusive Development Index is based on data (*The Inclusive Development Index 2018*)

Ease of Doing Business Index (Doing Business 2020: Comparing Business Regulation in 190 Economies) – measures the main economic, legislative and management indicators of business formation. The Ease of Doing Business Index measures:

– Launching a business: starting a business, employment, number of employees.

– Location: building permits; availability of electricity; property registration.

– Access to finance: availability of loans, protection of minority investors.

– Conducting business operations: payment of taxes, export trade; cooperation with the government.

Business security: the number of concluded contracts, solving insolvency problems.

Ukraine's position is 64th in the ranking with a doing business indicator of 70.2.

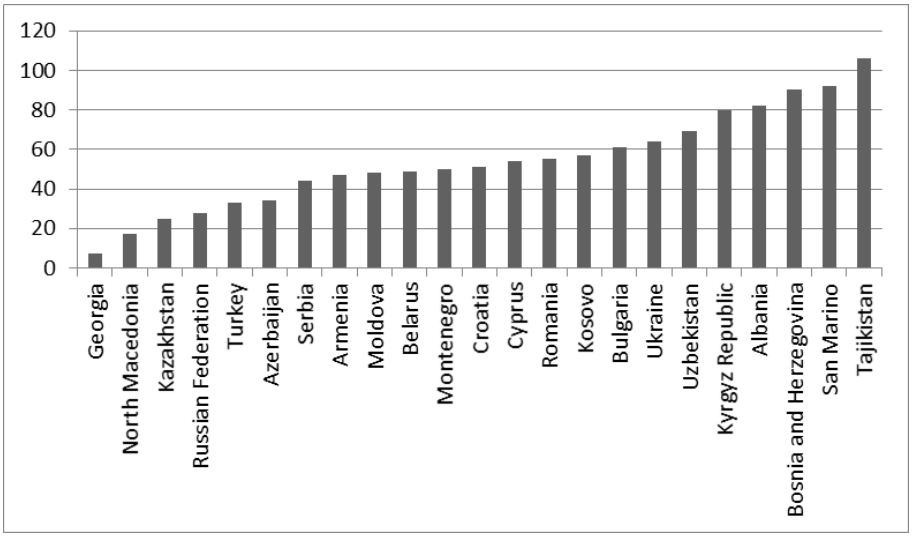

Fig. 2. The ranking according to the Ease of Doing Business Index is based on data (*Doing Business 2020: Comparing Business Regulation in 190 Economies*)

The Social Progress Index is a new way of measuring the success of our societies. This is a comprehensive indicator of real quality of life, independent of economic indicators. The Global Index: Overview is designed to complement and replace economic measures such as GDP.

The Social Progress Imperative programme defines social progress as the ability of a society to meet the basic human needs of its citizens, to establish conditions that enable citizens and communities to improve and maintain their quality of life, to create conditions for all people to develop their potential. Instead of emphasizing traditional measures of success, such as income and investment, the Social Progress Index measures 51 social and environmental indicators to create a clearer picture of everyday people life. Ukraine ranks 80th out of 149. The index does not measure people's happiness or life satisfaction, focusing on real life results.

The index includes:

1. Basic human needs: food and basic medical care, water and sanitation, housing and sanitation, personal safety (whether a person feels safe).

2. Welfare: access to secondary education, awareness, health and wellness, quality of the environment.

3. Opportunities: personal rights (protection of human rights), personal freedom and choice, social inclusion, access to higher education.

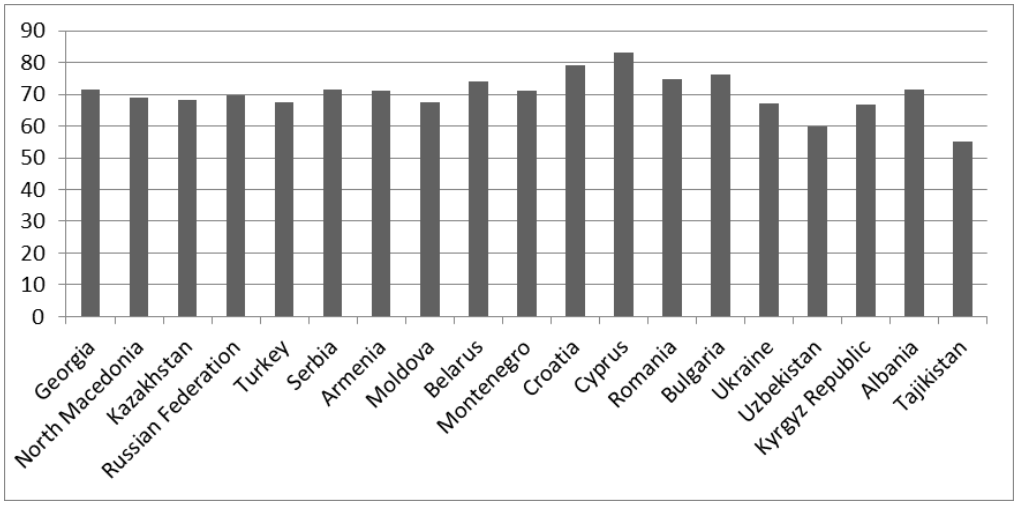

Fig. 3. The ranking according to the Social Progress Index is based on data (*Global Index: Overview*)

Note that all indices in one or another area are inherent in the input indicators of social entrepreneurship. However, in the field of inclusion and nature management there is a skew towards recovery, recreation, gaining experience, which is extremely relevant in the post-pandemic period.

Results and discussion.

In the post-pandemic period the social entrepreneurship definition and components are oriented to the development vectors such as environmentally oriented activities in the field of nature management, which in themselves entail inclusion. In the future, this direction of growth will be achievable for the tandem "state – enterprise – society" – overcoming the destructive impact on the environment, encouraging conservation and sustainable use of natural resources, making inventory of recreational areas, ensuring inclusive economic growth.

Therefore, the determination of indicators to be used in making an index of development of social entrepreneurship was carried out using definitions and characteristics of economic growth, inclusive growth and impressions/experiences in nature management. Thus, the research algorithm is formed (Fig. 4).

Based on the research algorithm, synthetic indicators of the social entrepreneurship development index should reflect their essence according to the selected classification features. However, there is a problem of establishing the boundaries of the study, because the set of indicators can be constantly increasing, moving beyond the phenomena inherent in the sphere of research. Therefore, international experience of research indicators of sustainable development (Mikhno, Koval, 2021), the selection of indicators in the study will be carried out on the principle of multi-indicator immersion, as one in which the limits are set beyond the identifying features.

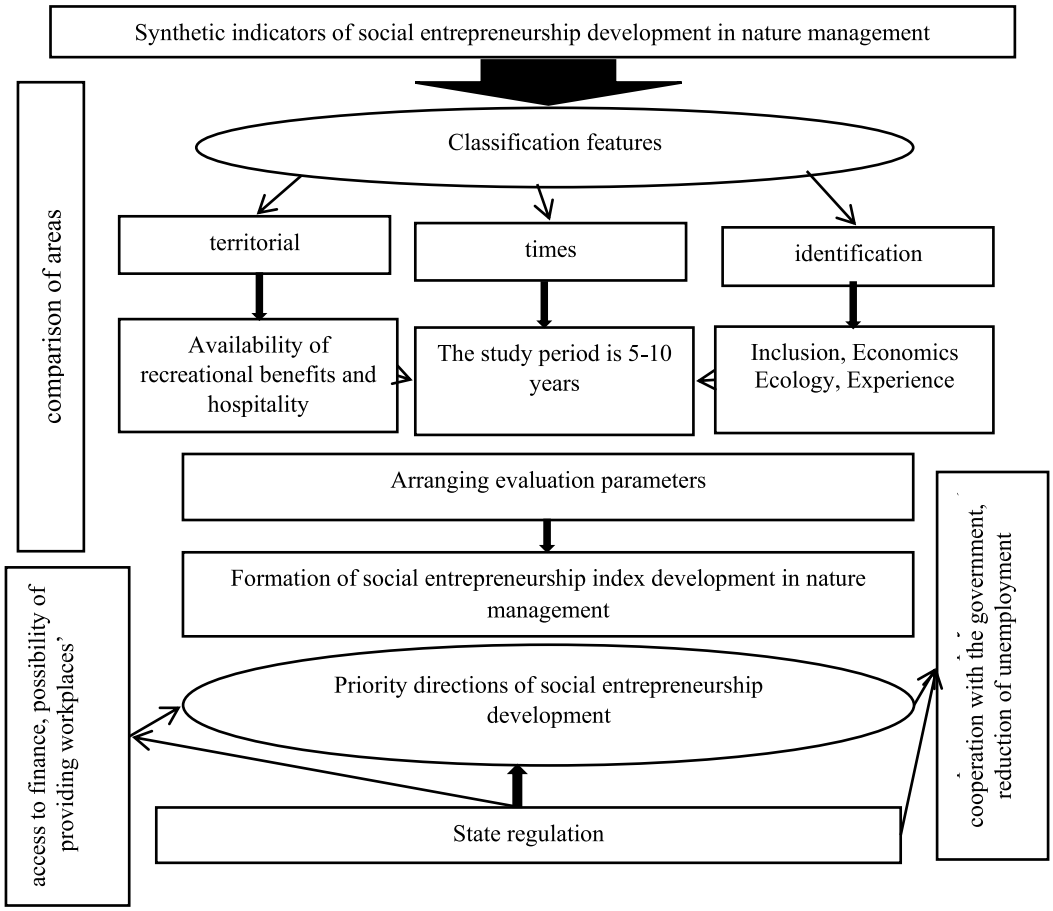

Fig. 4. Algorithm of social entrepreneurship inclusive development in nature management

In foreign research publications, this is a fairly common method. Thus (Levett, 2002) Sustainability Indicators – Integrating Quality of Life and Environmental Protection considers sustainable development by multi-indicator immersion, proposing to move away from the idea that sustainable development is a crossroads of social, environmental and economic goals, and considering instead the environmental goal as the core of the concept of sustainable development, which is formed based on the needs of society that can be solved by the economy. Thus, sustainable economic development depends on and must take into account environmental and social constraints.

Other views using the same multi-indicator immersion model are discussed (Brady, 2005) in *Environmental management in organizations*. The IEMA Handbook considers sustainable development through the prism of the production process in organizations and work model multi-indicator immersion as an alternative to the sustainable development three-ring model, where economic progress depends on social activity, and economic activity acts as an auxiliary in ecological and social well-being. The author proves that such a model of sustainable development, rather than a three-ring one, reduces social and environmental risks from economic activity, taking into account the impact of manufactured products or services on the environment.

The initiative of the WHO Regional Office for Europe (World Health Organization, 2012) examines welfare using a multi-indicator immersion model, where the circle boundary includes public administration, economy, environment, which interact with society to directly influence factors of individual well-being that include: health (physical and psychological), relationships, personal finances, education and skills, work, housing. The inner circle is defined by personal well-being, which should take indicators of happiness, life satisfaction and affective experience. Methods for measuring personal well-being are based on questionnaires and observations of a person's behaviour during the day including changes of mood, or compensation of some components for others.

The report (Ahmad, 2020) Sustainable Neighborhood Development in Emerging Economies: A Review considers sustainable development according to the multi-indicator immersion model as an economic one to achieve economic adequate benefits to society within ecological limits.

Tuti Haryati (Su, 2014), consider the impact of sustainable development on the cost of commercial office buildings using the multi-indicator immersion

model approach. The authors consider three concentric circles: the most remote the environment, society and the economy at the center. This alternative concept puts economic factors at the center as the basis for wealth creation, which is a further development engine, but at the same time limited by environmental and social parameters. The authors argue that creation of green buildings will provide a social effect for workers due to the provision of more environmentally friendly working conditions, which will increase the economic effect, as the main goal to be achieved due to work capability and public health and greater green structures sustainability.

Dixon (2011) considers sustainable social development as the basis for achievement of economic growth, well-being and happiness of the population, arguing that not only does environmental sustainability require intervention and reorientation of state regulation, but social sustainability is the at core of achieving economic and environmental needs.

Pei-Ing (Wu, 2014) analyzes different views on sustainable development: the approach to environment monetization, economy and society using the multi-indicator immersion method proves that the better the aggregation environmental index, the lower the aggregation social index in achieving economic development.

In Russian *Dolls and Chinese Whispers: two perspectives on the unintended effects of sustainability indicator communication* (Lyytimäki, 2014), the authors propose to form a sustainable development indicator as a set of dolls that decrease in size and take into account the main features of the parameters. In the study (Kostetska, Laurinaitis, 2020) the index was formed using the "multi-indicator immersion principle" to establish a framework of indicators of digital technology use for transformation of individual sectors of the economy, reproducing the general index scheme and focused on measuring specific conditions (effects) of digital technologies that are directly related to a given economy sector. This approach allows use of a comprehensive sub-index and a set of indicators for the digital transformation of an economic sector as an independent full-fledged tool.

The report "The quality of the environment affects our happiness" confirms the importance of the natural environment for people in nationally representative household surveys. For example, asking how important environmental protection is for their well-being and life satisfaction, 88 % of respondents in a survey by the German Socio-Economic Group (SOEP) said it was important or very important. So, in response to the question how concerned they are about the state of the environment, 72 % say they are somewhat or very concerned. Similarly, 70 % say they are somewhat or very concerned about the effects of climate change.

Academic interest in the relationship between the environment and happiness was twofold: first, there was a real interest in how the environment affects people's subjective well-being. Work has also been done on using subjective well-being indicators for the monetary assessment of environmental factors, which are publicly available, often intangible, goods for which there are no market prices. The interaction of environmental factors with life satisfaction – a measure of experimental usefulness – and income assessment, this approach is called the experimental benefits assessment. Second, there is a growing interest in the effects of environmental behaviour on people's subjective well-being, and in turn, how people's emotional states can effectively encourage more environmentally conscious behaviour.

In psychology, there is evidence that when a person is in the natural environment, his mental well-being improves. There is a decrease in stress, growth of positive emotions, cognitive recovery and a positive effect on self-regulation.

Thus (Koval, Mikhno, 2019), analyzing the different approaches of the principle of multi-indicator immersion use, we note that the core of this model should be the main achieved goal, the next circles are those cores within which the goal is achieved. Thus, the model uses normalized social, environmental, and economic indicators to include them in a unique performance indicator.

Research analysis has shown that in the application of the index approach based on multi-indicator immersion principle, it is necessary to establish external and internal limits for the selection of indicators that would indicate the development of an inclusive economy in general and directly within each circle would be independent. The quality of the environment affects human health through the quality of air, water and soil, which is associated with the presence and density of hazardous substances. The quality of the environment is also essential for people who value the natural beauty and for whom amenities influence their life choices (e. g., place of residence) (Balestra and Davide, 2012). This sentence describes the situation of inclusive economy development in nature management.

This area of study is reflected in the contradictions of economic growth and natural resources use; social values and phenomena which affect people's experiences. Therefore, in order to combine nature management, inclusion, economic growth and experience, based on the multi-indicator immersion principle, using an index approach, we will identify indicators from existing international indices that are specific to social entrepreneurship in nature management.

External borders will be generalized by inclusive growth, namely indicators of the human contribution of productive country development, economic growth

is characterized by the limits of inclusion and comprise design, innovation and skills. Experience (Baranets, 2020) in nature management is formed by the internal circle of multi-indicator immersion, the functions of which are aimed at achieving a sense of environmental quality, attractiveness of the place, ideal space for communication, in the context of declared economic growth, inclusion and does not go beyond range of regulations based on nature management.

Thus, the conceptual approach of the social entrepreneurship index in nature management can be determined:

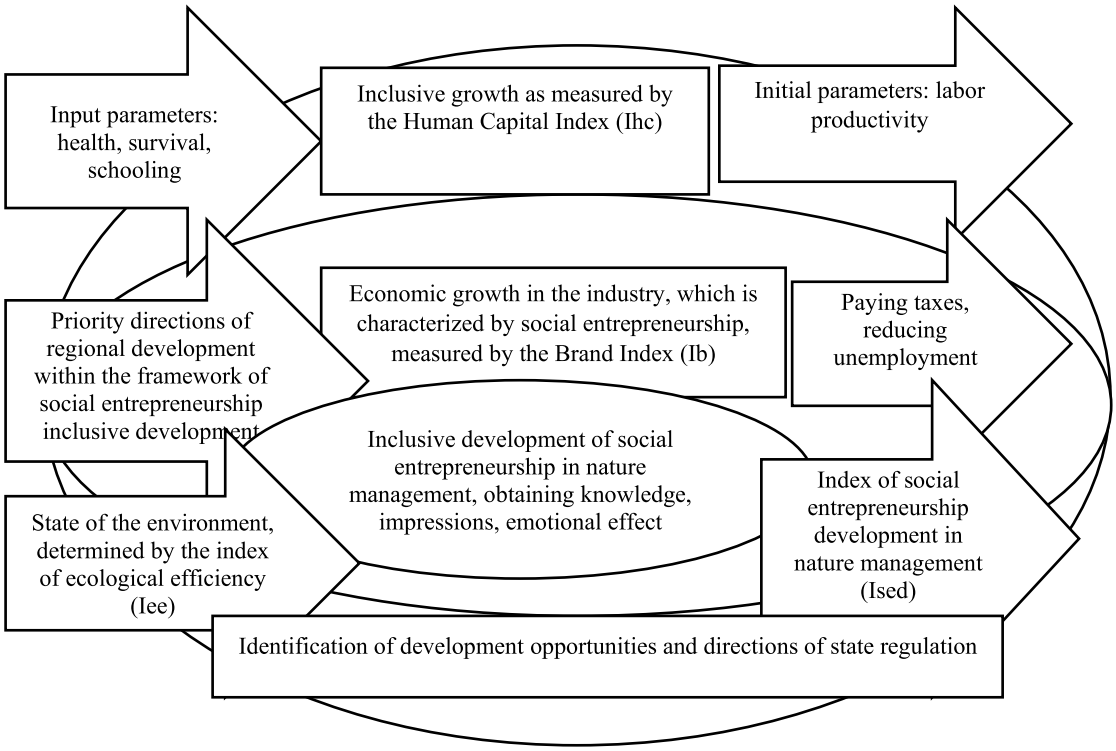

Fig. 5. Conceptual approach of the Social Entrepreneurship Index development in nature management

Classification features are based on the selection of indicators by territorial component; we selected 3 regions for calculations: Odessa, in which the main recreational potential is determined by the marine environment, Transcarpathia, in which forest, river and mountain recreation is concentrated, and Kyiv as a hospitality center.

A time period of 5 to 10 years was chosen as one in which can observe changes in indicators of the chain growth rate.

The identification feature characterises a multi-indicator immersion range and includes selection of synthetic indicators according to inclusive, economic and environmental indicators.

The inclusion scope is directly related to economic growth and nature, as defined by the OECD, can be calculated by the human capital index, which consists of knowledge, skills, abilities and other qualities that an individual possesses which are important for economic activity.

The International Bank (Human Capital Development Project) proposes to calculate the Human Capital Index by multiplying the indicators of the relative contribution of survival, schooling and health as impact productivity aspects, namely:

$$I_{hc} = Survival * Schooling * Health \quad (1)$$

$$Survival = \frac{1 - child\ mortality\ up\ to\ 5\ years}{1} \quad (2)$$

$$Schooling = e^{f\ (expected\ duration\ of\ schooling * \frac{unified\ test\ results}{625} - 14} \quad (3)$$

$$Healthh = e^{y_{ASR} * (Adult\ survival\ rate - 1) + y_{short\ stature} * \frac{Proportion\ of\ children\ who\ do\ not\ suffer\ from\ short\ stature - 1}{2}} \quad (4)$$

The percentage of short stature is recommended as one of the key parameters influencing the achievement of the Millennium Development Goals by 2030, namely the eradication of hunger.

The components of the Index in this case are presented as indicators of the relative contribution to productivity in comparison with the reference indicator of the full education course and full health. Parameter ϕ = 0.08 measures the return from each additional year of schooling. Parameters $Y_{ASR} = 0.65$ and $\gamma_{Short\ stature} = 0.35$ measure the increase in productivity due to improved health, using indirect indicators of health data on adult survival and short stature. The reference indicator of complete and high-quality education corresponds to 14 years of schooling and a unified test result of 625 points. The benchmark for good health means that the survival rate of children and adults is 100 percent, and the percentage of short stature is 0 percent.

When calculating Ihc, these indicators are used as weights. These weights were chosen because they are the same for different countries, and thus the differences between countries in the value of Ihc reflect only the differences in the variable values of the components.

The chain growth rate of Ihc is shown in Fig. 6.

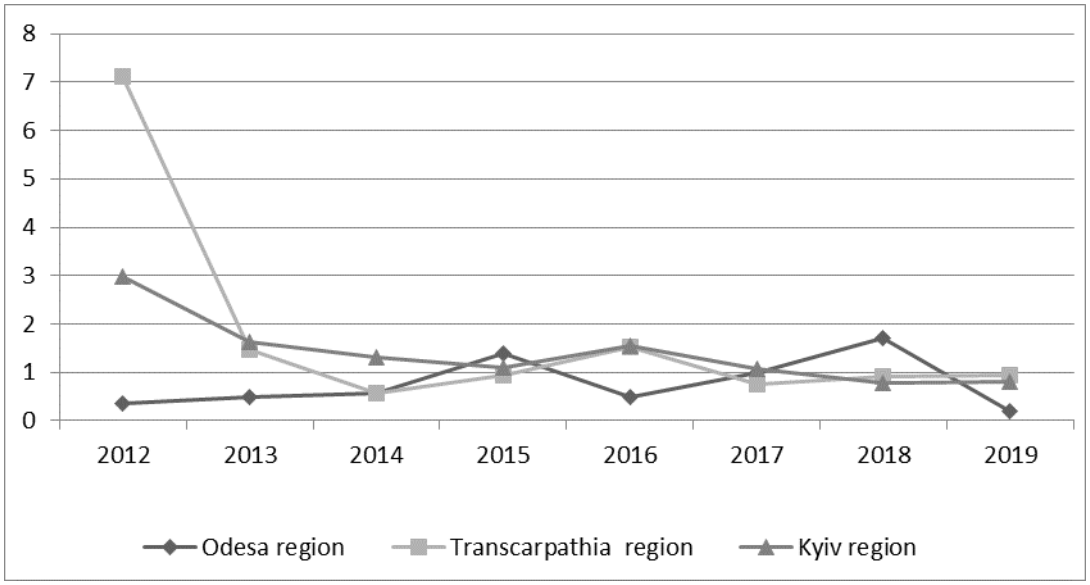

Fig. 6. Ihc chain growth rate for the period 2012–2019 is based on data (Metadata,2020)

The data presented in fig. 6 show that the human capital index in the selected regions has not changed over the past 5 years, which contradicts the general data for Ukraine, as our country scored 0.65 points and ranked 50th out of 157 overall world rankings. The growth of Ihc in studied areas is inhibited by the health status of the population, which is extremely poor, especially in Odesa region.

The economic growth range of social entrepreneurship in nature management can be characterized by the Brand Index. BDI (Brand Development Index) (Balestra & Dottori, 2011) or brand development index – an indicator that allows you to assess development / strength level of brand in a particular region and is measured in%.

$$Ib = \frac{\%\ from\ the\ total\ sales\ of\ the\ brand\ in\ the\ region}{\%\ from\ the\ total\ population\ of\ the\ country\ living\ in\ the\ region} * 100 \quad (5)$$

$$\%\ from\ the\ total\ sales\ of\ the\ brand\ in\ the\ region = \frac{revenue\ from\ the\ sale\ of\ the\ region's\ brand}{revenue\ from\ brand\ sales\ across\ the\ country} \quad (6)$$

$$\%\ of\ the\ total\ population\ of\ the\ country\ living\ in\ the\ region = \frac{population\ of\ the\ region}{population\ in\ the\ country} \quad (7)$$

In our specific study, it is advisable to calculate the Brand Index of the region by tourism indicators, namely the cost of tours sold and the number of tourists who were served by travel agents.

The chain growth rate Ib is shown in Fig. 7

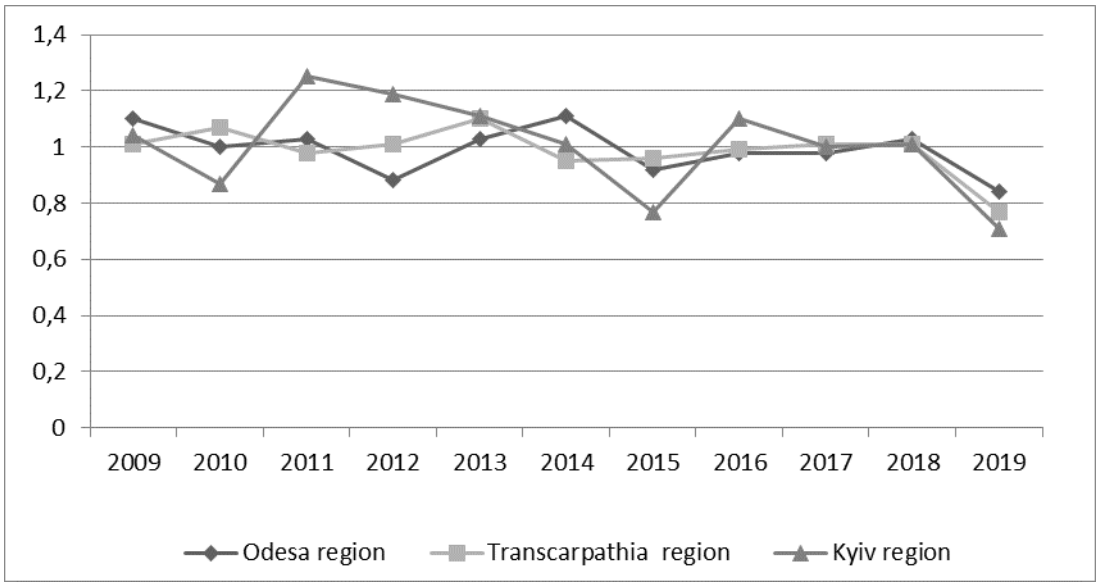

Fig. 7. Chain growth rate Ib by region 2009–2019 is based on data (Metadata,2020)

The overall decline in 2019 by Ib is due to the fact that at the end of 2019 the epidemiological situation worsened and the COVID-19 epidemic emerged. The overall Ib indicator for 2015–2018 had a constant positive growth rate, which characterizes the selected areas as those where signs of social entrepreneurship inclusive development in nature management by economic circle have been identified.

The ecological range of indicators can be characterized by the index of ecological efficiency which reflects achievements of countries in the field of natural resources management and their rational use.

In 2020, the Yale Center for Environmental Law and Policy (Metadata Environmental Performance Index, 2020) used 32 indicators in 11 categories (Table 1) to calculate the state of countries and find management solutions to overcome environmental crises.

Table 1. Framework of the environmental efficiency index (Iee)

Environmental efficiency index framework	
Ecological health 40 %	Ecosystem viability (60 %)
Air quality – 50 %	Biodiversity and habitat – 25 %
Water and sanitation – 40 %	Ecosystem services – 10 %
Heavy metal pollution – 5 %	Fisheries – 10 %
Waste management – 5 %	Climate change – 40 %
	Greenhouse gases – 5 %
	Agriculture (nitrogen content) – 5 %
	Water resources (wastewater treatment) – 5 %

The reduction of indicators to one dimension was carried out based on the rationing of individual indicators (according to formulas 8, 9). If the growth of unit indicators leads to an increase in unit estimates, the rationing of indicators is carried out according to formula 10, otherwise according to formula 11.

$$z_i = \frac{x_i - x_{min}}{x_{max} - x_{min}} \quad (8)$$

$$z_i = \frac{x_{max} - x_i}{x_{max} - x_{min}} \quad (9)$$

Where z_i – normalized value of unit indicators ($0 \leq z_i \leq 1$)

x_{max}, x_{min}, x_i – maximum, minimum, i-th value of a unit indicator.

The selected Ukraine regions can be characterized by the following data according to time series that show by how many times the current level of the Environmental Efficiency Index has changed compared to the previous level (Fig. 8).

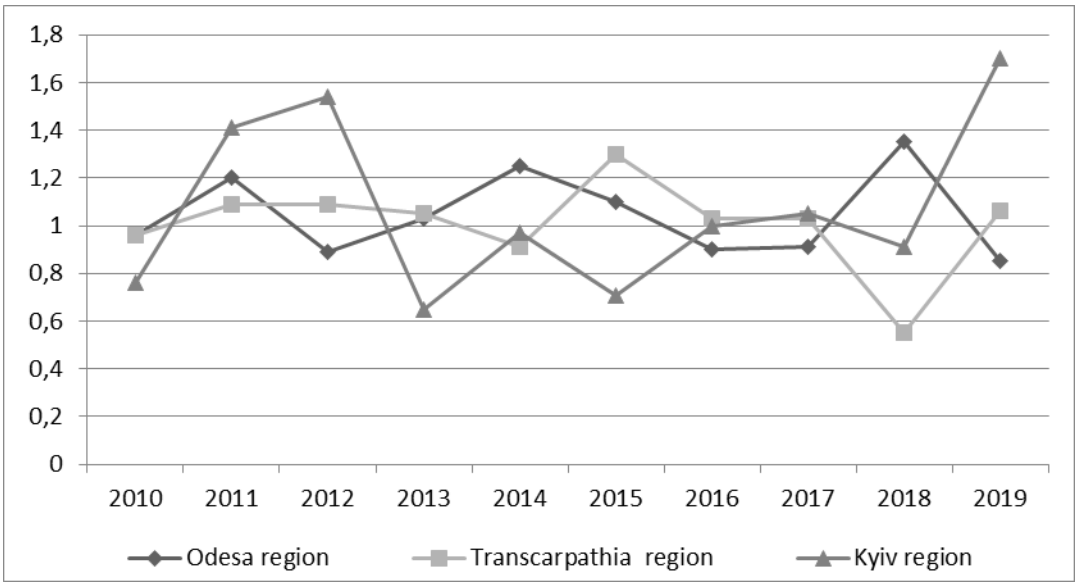

Fig. 8. The chain growth rate of Iee for the period 2009–2020 is based on data (Metadata,2020)

According to the figure, we note that Iee indicators have increased significantly over the past year in Transcarpathia and Kiev regions, while in Odesa they have sharply decreased, despite the fact that the dynamics of the index had been uniform in previous years. Therefore, it is necessary to indicate the weakest indicators for each region; namely in the Transcarpathia region there is an increase in the presence of greenhouse gases and nitrogen content in agricultural lands, in Odesa oblast the index of ecological efficiency was greatly influenced by indicators of biodiversity loss, ecosystem services, increased nitrogen content in agricultural lands and pollution of water resources of the oblast. Some negative points are also observed in Kiev region. Indicators that inhibit the growth of the environmental efficiency index include climate change and greenhouse gases.

Based on the experience of domestic scientists and international approaches for calculation of consolidated indices in this study, we propose to calculate the index of inclusive development of social entrepreneurship in nature management according to the formula of geometric mean (Ised) as indices of environmental efficiency, human capital and brand.

$$\mathrm{I}sed = \sqrt[3]{\mathrm{Iee} * \mathrm{I}hc * \mathrm{I}b} \qquad (10)$$

The values of Ised indicators are given in Table 2, and the chain growth rate in Fig. 9.

Table 2. Ised indicators by region

Year	Odessa region	Kyiv region	Zakarpattia region
2012	2.09	1.44	1
2013	1.54	1.77	1.1
2014	1.41	2.02	0.95
2015	1.33	1.9	0.96
2016	1.18	1.8	0.99
2017	1.14	2.32	1.01
2018	1.53	2.29	1.01
2019	0.79	2.23	0.77

Analysis of dynamics of indicators by selected areas shows that in 2019 the index tends to decrease. This is primarily due to the pandemic, which has increased the amount of disease in the regions and brought a decline in tourism.

A major influence on the Index, which inhibits inclusive development of social entrepreneurship in nature management in the country, is exerted by impact on all such indicators of the Environmental Efficiency Index and the state of health of the population. Therefore, the task of state regulation should primarily be based on overcoming these disparities.

Conclusion.

Identification of opportunities for inclusive development of social entrepreneurship in nature management indicates the presence of potential in the regions of Ukraine. The study proves that Ukraine

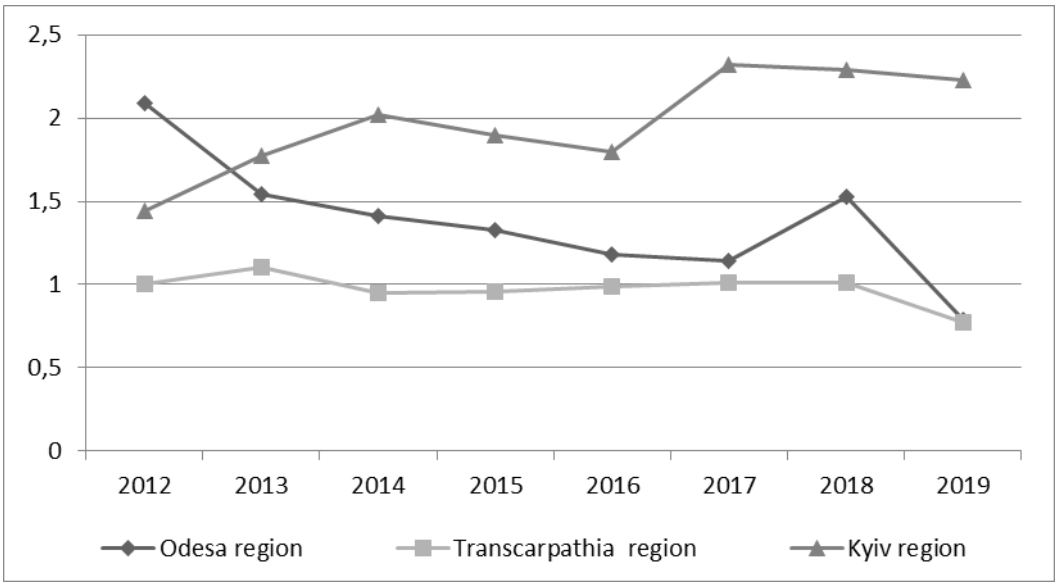

Fig. 9. The chain growth rate of Ised for 2012–2019 is based on data (Metadata,2020)

is very slow in its development in international index rankings, especially in the indicators of the globalization index (which is related to digitalization), human development (population health indicators), the international happiness index (population welfare indicators), ease of doing business index (due to difficulty in obtaining documentation and low financial support). Also, the analysis of consolidated international indices allowed us to identify synthetic indicators that were included in the social entrepreneurship development index in nature management in Ukraine. We note that almost all international indices include, to a greater or lesser extent, indicators of human development, which are measured by health status, population skills and environmental impact. Based on the achievements of foreign scientists in the field of sustainable development, a scientific vision and methodological support for the social entrepreneurship development in nature management on the multi-indicator immersion principle were formed to analyse in further detail the internal indicators outlined by inclusion, economy and ecology. The index calculations prove that the economic growth of the analyzed regions (Kyiv, Zakarpattia, Odesa) according to the measurement of the brand index has a positive impact and does not require structural changes in management. However, some of the inclusive and environmental indicators indicate the need for intervention in their regulation, in particular through the transformation of experience and awareness of the population of the economic growth of the region and the achievement of personal well-being.

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The discovery of structural elements and zones of hydrothermal alterations by using ASTER satellite data in the margins of Gadabay and Murovdag ore districts (Lesser Caucasus, Azerbaijan)

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Abstract. The article considers the discovery of structural elements, zones of hydrothermal alterations and mineralization in the margins of Gadabay and Murovdag regions and the study of prospective areas for mineralization characterized by them by using ASTER satellite data. The main purpose of the research is the definition of the lithological composition of rocks, ring and linear structures and zones of hydrothermal alterations with the help of remote-sensing methods and by better technological development of special radiometric data. In order to detect the lithological composition of associated rocks of alteration zone of endogenous ores, 14 channel data of ASTER has been used. By using stereoscopic images obtained from ASTER data, it was determined that hydrothermal alterations are mainly represented by alunitization, kaolinization, sericitization, silication, pyropilitization and silification in the studied ore regions. These changes were shown to be characteristic for copper-porphyry, gold-copper pyrite, copper-polymetal and gold-copper-porphyry deposits. Strip ratios, principal component analysis (PCA), minimum of noise fraction (MNF) and selection method for least squares (LS) have been used to map hydrothermal alteration zones. The ring structures detected in the area, different fault fractures and lineaments are assessed as favourable geological structural factors for alteration and mineralization. The results obtained by ASTER image analysis confirm the presence of derivative minerals which are considered to be the product of hydrothermal alterations which are densely concentrated (kalium spathization, kaolinization, serictization, pyrophyllitization, alunitization) has been confirmed. The points each with private coordinates have been determined (defined) within separate areas with the help of remote data and relevant anomalous maps prepared. These points are considered favourable geological condition in terms of the type and intensity of hydrothermal alterations in the area. Such areas are considered a sign of indirect search significant for the detection of copper-polymetallic, copper-porphyry, copper-pyrite and gold-pyrite type of mineralization with epithermal origin in the region.

Keywords: Gadabay and Murovdag, ASTER, structural elements, hydrothermal alteration, mineralization, prediction.

Виявлення структурних елементів та зон гідротермальних змін за допомогою супутникових даних ASTER на окраїнах Гадабайського та Муровдазького рудних районів (Малий Кавказ, Азербайджан)

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Анотація. У статті розглядається відкриття структурних елементів, зон гідротермальних змін та мінералізації на окраїнах регіонів Гадабай та Муровдаг та дослідження перспективних районів мінералізації, що характеризуються ними, за допомогою супутникових даних ASTER. Основною метою дослідження є визначення літологічного складу гірських порід, кільцевих та лінійних структур та зон гідротермальних змін за допомогою методів дистанційного зондування та кращої технологічної розробки спеціальних радіометричних даних. З метою встановлення літологічного складу вміщуючих порід зони зміни ендогенних руд використані 14-канальні дані ASTER. За допомогою стереоскопічних зображень, отриманих за даними ASTER, було визначено, що гідротермальні зміни в основному представлені алунітизацією, каолінізацією, серицитизацією, силікатизацією, піропілітизацією та силіфікацією у досліджуваних рудних регіонах. Показано, що ці зміни характерні для мідно-порфірових, золото-мідно-піритових, мідно-поліметалевих та золото-мідно-порфірових родовищ. Співвідношення смуг, аналіз основних компонентів (PCA), мінімум шумової частки (MNF) та метод вибору для менших квадратів (LS) використовувались для картографування зон гідротермальних змін. Кільцеві структури, виявлені в районі, різні тетконічні порушення та діниаменти

оцінюються як сприятливі геологічні структурні фактори для зміни та мінералізації. В результаті отриманого за допомогою аналізу зображень ASTER підтверджено наявність похідних мінералів, що вважаються продуктом гідротермальних змін, які щільно розташовані на території (калішпатизація, каолінізація, серіатизація, пірофілітізація, алунітизація). Точки, кожна з своїми координатами, були визначені (розділені) в окремих районах за допомогою віддалених даних та підготовлені відповідні карти аномалій. Ці пункти вважаються сприятливим геологічним середовищем з точки зору типу та інтенсивності гідротермальних змін на даній території. Такі райони вважаються ознакою непрямого пошуку, значущими для виявлення мідно-поліметалічного, мідно-порфірового, мідно-піритового та золото-піритового типу мінералізації з епітермальним походженням в регіоні.

Ключові слова: Кедабек і Муровдаг, ASTER, структурні елементи, гідротермальні зміни, мінералізація, прогноз.

Introduction.

Cosmic, multi-spectral systems such as Landsat MSS, TM and SPOT possess spectral channels ranging from 4 to 7. Landsat MSS data is mainly applied during the structural and geomorphological interpretation on a regional scale (Goetz et al., 1983; Abrams et al., 1983; Perry, 2004).

Using ASTER (Advanced Spaceborne Thermal Emission and Reflection) data, the wide application of the potential opened up by the discovery of ore deposits within ore regions and areas and application of satellite spectrometers in the spatial definition of mineral indicators in various geological conditions have been observed in recent times (Abrams et al.,2000; Sabins 1999; Spatz et al., 1994; Watson et al., 1990; Tommaso et al., 2007). ASTER covers visible, near infrared (VNIR), short-wave infrared (SWIR) and thermal infrared (TIR) spectral areas with 14 channels possessing high spatial, spectral and radiometric solubility properties. (Yamaguchi et al., 1998; Abdelsalam et al., 2000; Abrams and Hook, 2001).

In recent years, the use of ASTER images, especially the high spatial and spectral results of ASTER, as well as the availability of obtaining three-dimensional stereoscopic images allow us to apply this method widely in various spheres of geology. By applying spectral and thermal features of ASTER data, they are used in the investigation of geological features, the definition of hydrothermal –metasomatic alteration zones and mineralization zones which were formed associated with ore deposits, in the discovery of various tectonic structural elements, particularly linear and ring structures and in the solution of other geological problems (Rowan et al., 1977; Goetz et al., 1983; Boardman et al., 1995; Abdelsalam et al., 2000; Papp and Cudahy, 2002; Kruse et al., 2003; Perry, 2004). ASTER data are widely applied in the search and exploration of ore mineral deposits, two channels of SWIR are applied in the discovery of mineralization areas associated with altered rocks (Podwysocki et al., 1984; Okada et al., 1993; Sabins, 1996; Sabine, 1997; Abdelsalam et al., 2000).

According to the data on VNIR/SWIR surface reflection features, alteration processes of minerals, such as alunitization, kaolinization, sericitization, silicification and propylitization have been recorded.

As is known, the Gadabay and Murovdag ore regions are characterized by wide development of copper-porphyry, gold-copper-pyrite and copper-polymetallic, copper-arsenic and other ores and their proper hydrothermal alterations. The detectability of hydrothermal alterations and mineralization zones based on remote-sensing data create wide opportunities for conducting effective geological researches in this area.

The main purpose of the research is to discover hydrothermal alteration and mineralization zones, ring and linear structural elements, playing a significant role in the localization of noble and non-ferrous metal mineralization in the Gadabay and Murovdag mining districts by using ASTER data.

Materials and research methods.

The images related to a ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) receiver which was set over a TERRA satellite platform have been used in the article. ASTER module has resolution accuracy consisting of totally 14 spectral bands including 3 spectral bands in Visible Near Infrared (VNIR), 6 spectral bands in Short Wave Infrared (SWIR) and 5 spectral bands in Thermal Infrared field. VNIR bands of ASTER have resolution of 15 meters, SWIR bands-30 meters and TIR bands 90 meters. A single ASTER image covers an area of 3600 km^2 within the frame of 60km x 60 km. The data shown here allow us to study the mineralization and alteration in detail.

The examination of promising areas separated by remote sensing has been checked as a result of field observations and testing work and results were assessed.

Remote sensing analysis of the ASTER data used in the preparation of the article was carried out in three stages: In the first stage, preprocessing analysis was carried out combining spectral bands dealing with initial satellite data. In the second stage, the analysis directed to the definition of tectonic elements, obtaining stereoscopic image and mineralogical mapping, as well as lithological mapping analysis were carried out. In the third stage, combining all the data acquired from the results of analysis in the environment of the geographical information system, the work was carried out in the direction of definition of structural elements and hydrothermal alteration zones.

Remote sensing was carried out in the region by complex research consisting of a special program complex, facilitation and image processing technique.

Geological position of the research area. The research area is located in the territory of Shamkir and Gadabay regions on the north-eastern slope of the Lesser Caucasus between longitudes 45° 05 ¹20ᴵᴵ E and latitudes 40⁰02¹80ᴵᴵ-40⁰04¹40ᴵᴵ N (Fig. 1). Gadabay ore district is located in the axial zone of the large Shamkir horst uplift of the Lok-Karabakh zone. The complexity of its tectonic development and its position in the large block structure of the Lesser Caucasus depend on the occurrence forms and scale of fault structures. (Geology of Azerbaijan, 2005; Shikhalibeyli, 1996). It was mentioned that deep fault structures of the ore district are hereditary beginning from the Baikalian structure to the Hercynian epoch (Shikhalibeyli, 1996). The main feature characterizing the region is extensive development of Bajocian-Barthian volcanogenic occurrences and plagiogranite – gabbro-diorite-granodiorite formation intrusively cutting through them (Geology of Azerbaijan, 2001). As the oldest mining region of the Caucasus, Gadabay ore district is characterized by gold-copper-pyrite, copper-gold porphyry, copper-polymetallic and copper-arsenic mineralization.

The Murovdag anticlinorium is located south-west of Dashkesan and north of Toragachay. As a boundary structure separating two facial tectonic zones with different properties, the Murovdag anticlinorium is located between two structure-formation zones (Lok-Karabakh and Goycha-Hakari) of different ages and different geological history of development (Shikhalibeyli, 1996; Abdullayev et al., 1988). This structure composes of mainly Middle Jurassic volcanogenic genesis and granitoid massifs cutting them through (Geology of Azerbaijan, 2001). This ore district is characterized by copper-gold-porphyry, copper-pyrite, copper-polymetallic and gold-polymetallic mineralization.

Due to the wide development of metasomatic alterations and epithermal mineralization associated with them both in Gadabay and Murovdag ore regions, the remote sensing data like ASTER is significant in the lithological mapping and initial stage of the investigation work.

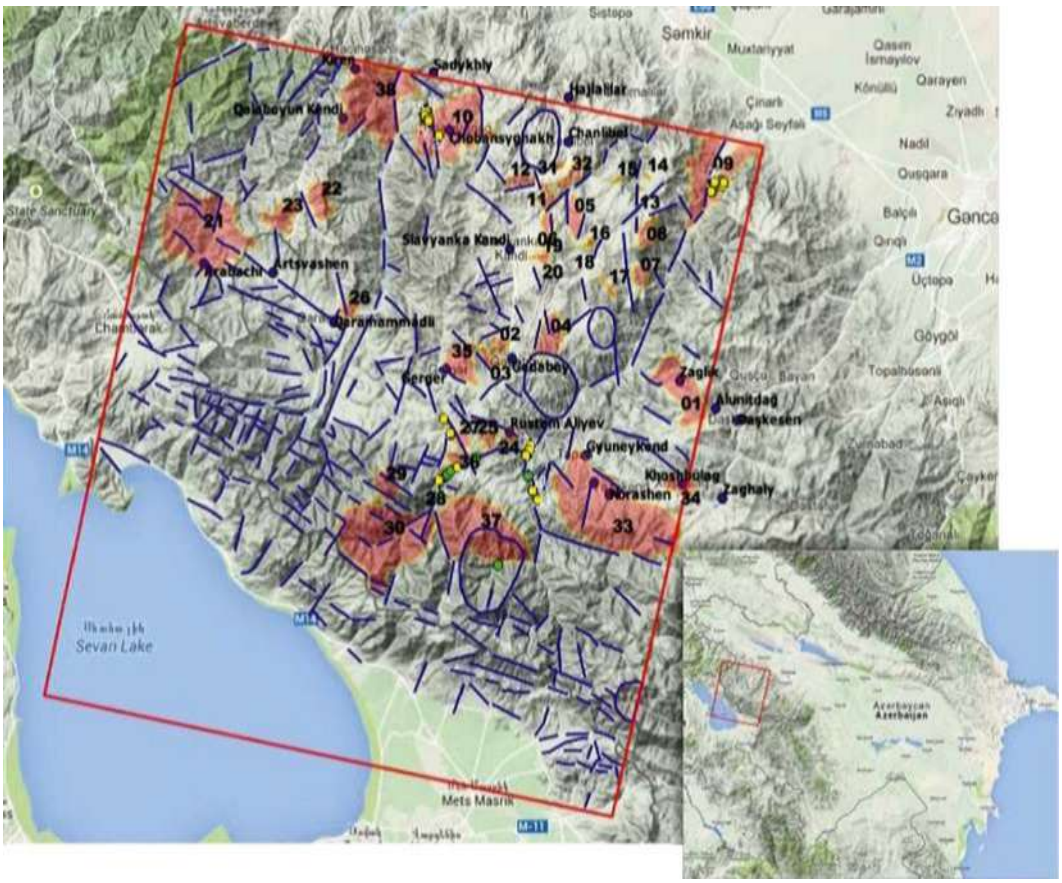

Fig. 1. Geological and tectonic position of Gadabay and Murovdag ore areas

The analysis of stereoscopic image.

There exists an infrared telescope which provides the view of ASTER satellite in the vertical direction from the sky and receives the backward image in the same spectral band. This infrared telescope captures obtain pairs of stereo images (3N and 3B) with 27.6^0 angle and 0.6 high ratio percentage. This peculiarity has been used in the formation of numerical elevation model and obtaining three-dimensional stereoscopic image (Fig. 2 and 3). Two individual telescopes were set to the VNIR receiver in order to reduce breakages in the images and to obtain a nadir view and backward view. VNIR, possessing totally 3 bands (1–2–3) and a single band with stereo image features is received in 0.52 μm – 0.86 μm wave length (Yamaguchi et al., 1998; Abrams and Hook, 2001). Stereoscopic image receivers have capacity of showing the other three-dimensional band receiver 27.6^0 backward which was set in the orbits. The basic height ratio in the stereo images is B/H=0.6. VNIR possesses ± 24^0 image capacity from the vertical direction towards the cross. The area of the image is 60 km x 60 km, the resolution of the image is 15 meters (Abrams, 2000; Abrams et al., 2001).

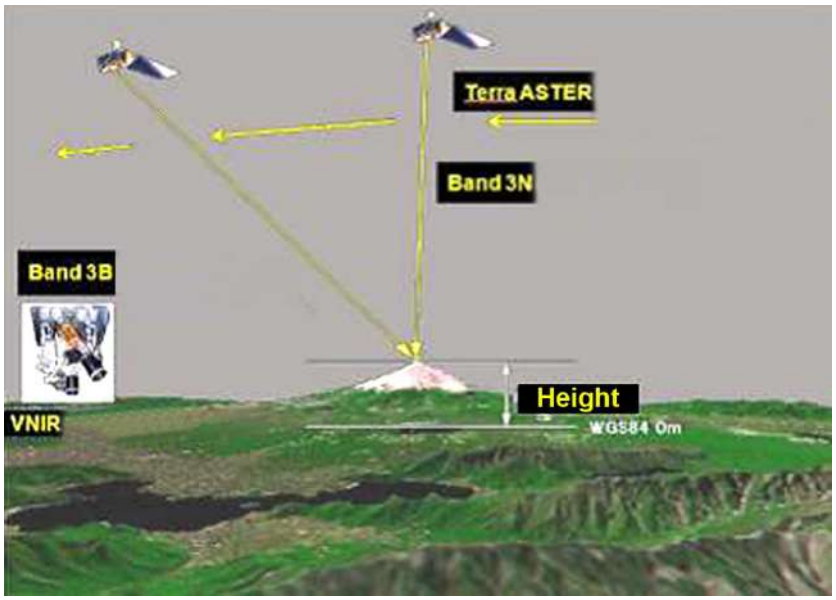

Fig. 2. Stereoscopic images obtained by using 2 pieces of VNIR receivers belonging to ASTER.

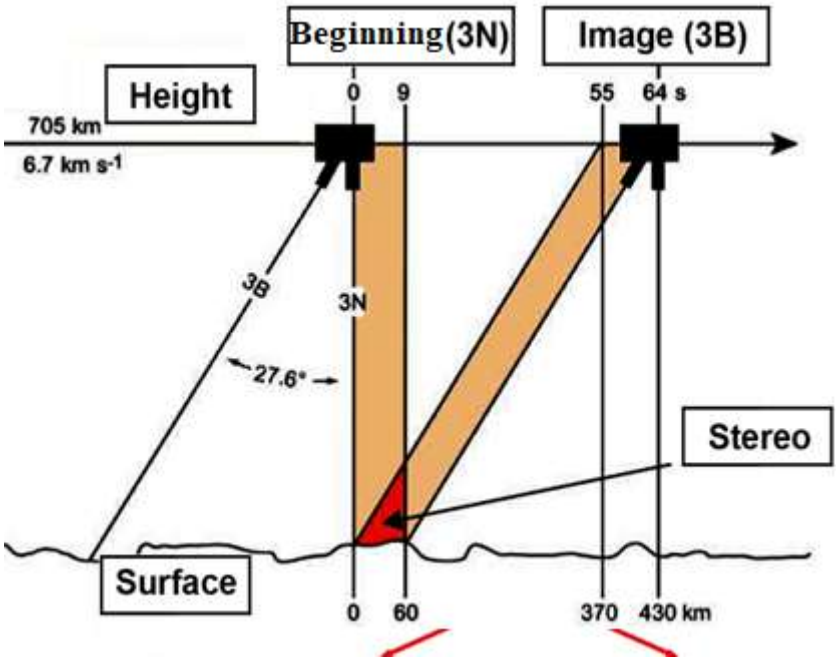

Fig. 3. The geometrical form of ASTER VNIR stereo image.

Note in Fig. 3 **Beginnig** should be **Beginning**

The standard surface radiance data product for all 14 channels was used in the classification. The 15-meter VNIR channels and 90-meter TIR channels were resampled and registered to the 30-meter spatial resolution of the SWIR channels (Zhang et al., 2007). A flowchart of the classification process is illustrated in Fig. 4.

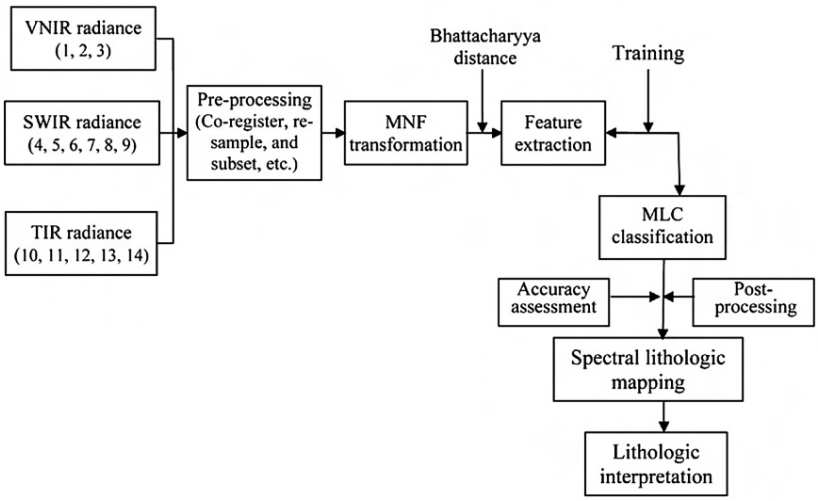

Fig. 4. Flowchart for lithologic information retrieval from ASTER data (Zhang et al., 2007).

The limitation of tectonic structural elements by using stereoscopic analysis. The obtainment of tectonic structural elements is possible by using stereoscopic images based on the analysis of accurate and precise stereoscopic images (Yamaguchi et al., 1998; Abrams and Hook, 2001).

For the purpose of discovering new linear and ring structures in the tectonic setting of the research area, the classification of structural elements and definition of strike directions are significant in the region. Stereoscopic images allow us to carry out accurate work approximately up to 1–35,000 scale. The greatest advantage of stereoscopic images is the detection of structural elements and the survey of hydrothermal alteration zones within the area of 3,600 km. From this point of view, by obtaining photogeological data from stereoscopic images, the structural elements have been mapped taking into account the fractures, caldera-type structures, linear and ring structures, different lithological units and compositions. These structural elements belonging to the region were studied by using geomorphological elements in the earth (Crosta and Filho, 2003; Zhang and Pazner, 2007; San et al., 2004).

The other method used in the definition of geological features of ASTER images is the discovery of geological structures by stereo image analysis. Fault systems and fault zones, caldera type structures, fracture structures like anticlinal and synclinal are defined by stereoscopic analysis (Babazade et al., 2018). The definition of the features of tectonic faults in the area outside the minerals in hydrothermal alteration zones is potentially promising as the discovery and survey of ore mineral deposits in remote sensing work are considered the main factors from the point of view of investigating the areas selected as a target for exploration work (Koronovski and Dmitrieva, 1990; Milovskiy et al., 2018).

Based on the ASTER data, particularly by obtaining stereo images and analyzing them, the definition of structural elements belonging to the Gadabay ore region, especially ring structures, are considered the basic structural factor in the determination of ore distribution and determining structures (Babazade et al., 2018; Milovskiy et al., 2018). As a result of decipherment of cosmic, medium and large-scale height images of the area surrounding the Gadabay ore region and ground control strips, the fault fractures bordering tectonic blocks with small size (5–10 km.) are separated. These structures look much better over Middle Jurassic age rocks and they are visible in the form of narrow, rectilineal stripe, forming dark photo shades on account of the hydrothermally altered rocks, as well as plant cover (Babazade et al., 2018).

Within the boundaries of the Jayirchay copper-porphyry deposit entering the Gadabay ore region, a concentrically micro circular structure was defined. Different parts of this structure are visible in the form of a series of arched fault fractures in the erosional section. The width of alteration zones varies between 10–15 km. along the fault fractures. Here the rocks have been exposed to cataclysmic hydrothermal alterations such as silification, kaolinization and cutting. Here, sericite facies of derivative quartzites play a significant role in the localization and concentration of copper-porphyry mineralization (Babazade et al., 2015).

Caldera-type ring structures playing a positive role in the localization of endogenous type mineralization in the area of volcanic edifices of Karadag Khar-Khar ore district have been mentioned. These structures are considered significant from the point of view of the determination of promising areas of mineral potential (Babazade et al., 2015).

The Shamkir ring structure is considered the largest one among the studied structures in the research area. Along with the Shamkir ring structure, several, relatively small-sized circular, ellipsoid and arched structures are located here (Gadabay, Slavyanka, Zahmatkend, Kharkhar, Karadag). Their sizes are 2–5 km in the width section. Along the fractures striking in the meridional (transversal) direction, outcrops of Atabey-Slavyanka plagiogranite, Gadabay and Jayirdag intrusive are observed in these structures (Geology of Azerbaijan, 2003).The above-mentioned ring structures are interesting from the point of view of mineralization. The rock complexes cut by them have been exposed to different formational types of hydrothermal-metasomatic alterations in most cases and they are observed with various types of mineralization (copper-polymetallic, copper-porphyry, gold-pyrite, copper-arsenic, sulphur-pyrite) (Abdullayev et al., 1988).

The Asrikchay volcanic-plutonic ring structure is located in the north-eastern part of the Shamkir ring structure, in the basins of Tovuzchay and Asrikchay. The size of the structure along the width section is 15 km. Paleozoic metamorphic shales, Lower Jurassic terrigenous-sedimentary rocks and subvolcanoes with acid content cutting them through participate in the central part of the structure. As a result of crossing fault fractures of different directions, a block-like structure was formed in this area. The contact zones of the majority of ring structures are limited with volcanogenic and volcanogenic-sedimentary rock complexes with different content. Most of the revealed ring structures (fractures) are of magmatic origin and in their central part stand relatively ancient magmatic complexes with deep source (Atabey-Slavyanka, Gadabay, Gianbyr and other intrusives). Small scaled ring structures are bordered with separate volcanic edifices, subvolcanic masses and small intrusives in the area (Geology of Azerbaijan, 2003). In places some ring structures of unknown origin stand out separately in the region. They are distinguished by better decipherment in a form of concentric lines in cosmic images for their geomorphological features (Babazade et al., 2018).

Along the tectonic structures revealed within the boundaries of the Murovdag ore region, spatially and genetically hydrothermal-metasomatic alterations of the surrounding rocks (silification, pyritization, kaolinization, sericitization and etc.) are observed. More intensive concentration of Au, Cu, Mo, Pb, Zn and other mineralizations with epithermal origin associated with these alterations occurred under the impact of postmagmatic activity of the intrusive with plagiogranite and gabbro-granodiorite content and solfatara processes. This process is in close genetic relation with Middle-later Bajocian Middle underlying rocks with acid content which possess post- magmatic activity of acid vulcanites and granitoids (Geology of Azerbaijan, 2001).

The detection of hydrothermal alteration zones and mineralization areas. The rocks located in the areas where extrusive and volcanic-dome edifices have developed and also in the contact parts of hypo volcanic and subvolcanic masses have undergone to hydrothermal-metasomatic alterations in the Gadabay ore region.

The possibility of the detection of hydrothermal alteration zones based on remote sensing data creates a wide scope for conducting effective geological researches in this area. From this point of view, by using remote sensing data the detection and research of alteration zones have been carried out in the Gadabay and Murovdag ore regions. Components of variability have been defined according to diagnostic spectral band among basic components (Boardman, 1988; Boardman et al., 1995). Alteration zones defined by remote sensing, geological survey and field inspections have been accurately analyzed.

The results show that OH alterations are mainly represented by k-spars, kaolinization, sericitization, silication, pyrophilitization. Such alterations are considered characteristic for copper-porphyry, gold-copper-porphyry deposits Fe^{2+} (Fe^{3+}) alterations are referred as a result of pyritization. Such kinds of alterations are estimated as an indicator of polymetallic deposits in the area (Arnott and Zentilli, 2006; Sabins, 1999).

ASTER data was widely used in the detection of minerals in the hydrothermal alteration zones. One of the most significant methods for mineralogical cartographical analysis is band areas. This method has been applied in two different ways (Abdelsalam et al., 2000; Abrams, 1983).The first method is band areas obtained by using mineral spectral information from spectral archives in the programs used for remote sensing analysis. The second method is the band areas created by using spectral information obtained from the rock samples in the territory and areal spectrometry. The technique of band area is applied particularly to multispectral and hyperspectral satellite data. Each mineral possesses in its nature different chemical and physical properties. Due to this difference, each mineral shows different spectral features (Fig. 5). These spectral peculiarities are the most significant features used for distinguishing minerals from one another (Ninomia,

2003; Goetz et al., 1983).The technique of band area uses these differences. The most significant factor applied in the band area method using this spectral information is reversible and absorption differences in the spectral graphics related to the minerals. Using the programs of the remote-sensing analysis of these differences, in the image of the reversible belt appearing in the ratio with the absorption band against ASTER diapason, they were defined by obtaining light-coloured areas (Watson et al., 1990; Gupta, 2003). For example, light-coloured zones are obtained in the new image to be created in the ratio of the fourth band with the fifth band for detecting alunite mineralization. These zones have been determined as the areas of anomaly of the alunite mineral. The mineralogical cartography is carried out by the technique of the band area, which is considered an easy and significant method (Okada, et al., 1993; Papp and Cuday, 2002).

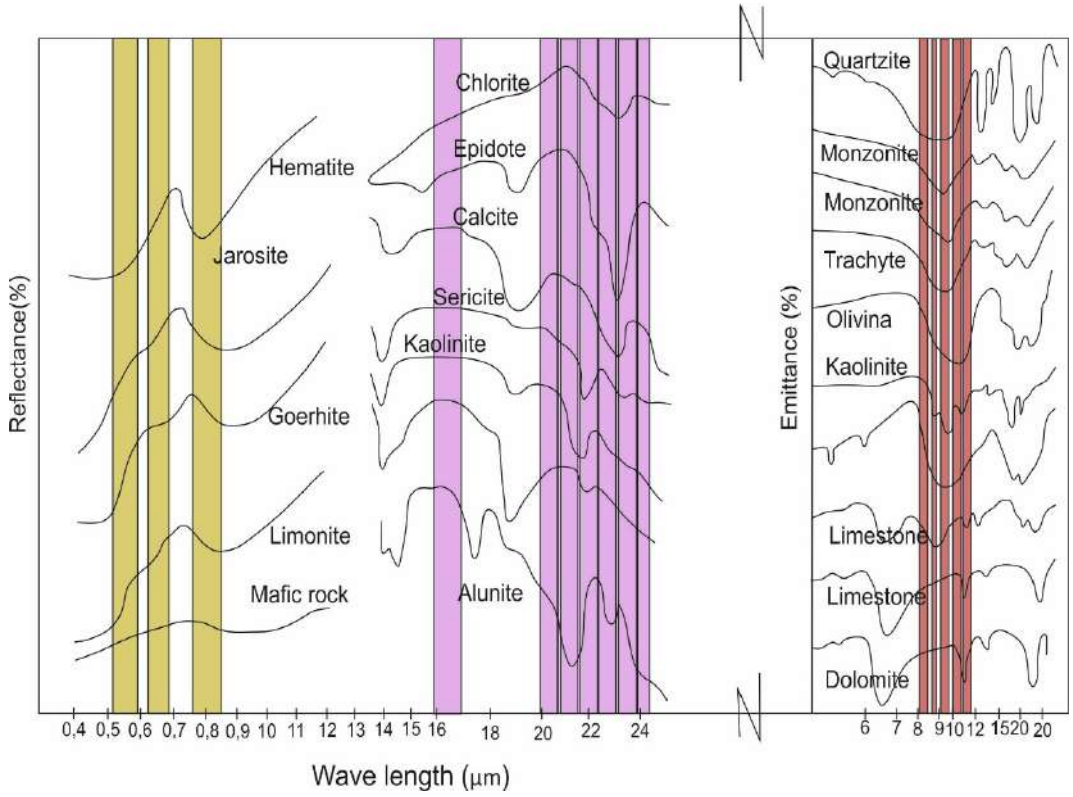

Fig. 5. Samples with the bands used for the discovery of different minerals and rocks in ASTER, VNIR, SWIR and TIR diapasons.

During the investigation and survey of ore deposits, kaolinite, alunite, sericite, calcite, muscovite, iron oxides give significant information in terms of mineral alterations, particularly the definition of the type of hydrothermal alterations. (Morton, 1977; Lillesand and Kiefer, 2004). For that reason, for the purpose of creating the distribution map of the hydrothermal alteration zones, anomalies were determined. The density of anomalies is observed in the distribution map of the obtained iron oxide anomaly in separate areas of the Gadabay ore district (Babazade et al., 2018).

Density is observed in the Gadabay and Murovdag regions in the obtained distribution map of iron oxide anomaly. The extension of these anomalies continues up to the borders of Armenia and the distribution of anomalies in larger areas attracts attention (Fig. 6).

As it is known, the significance of alunite minerals is important in the definition of epithermal and hydrothermal ore deposits. The distribution is observed in many areas in the distribution map related to the revealed alunite mineralization anomaly (Fig. 7)**.** The anomalies observed in Goyche Lake and around it can be false. The cause of these anomalies can be associated with clay minerals which appeared as a result of the lake drying up, its traces can be found there (Rowan et al., 1977; Sabine, 1977).

The distribution of kaolinite obtained by the application of the kaolinite index method is observed in larger areas based on the result obtained by the band area. (Tommasa and Rubinstein, 2007; Crosta and Filho, 2003). In the conducted field research work these areas occupied a place among the spheres which are essential targets for hydrothermal zones (Fig. 9).

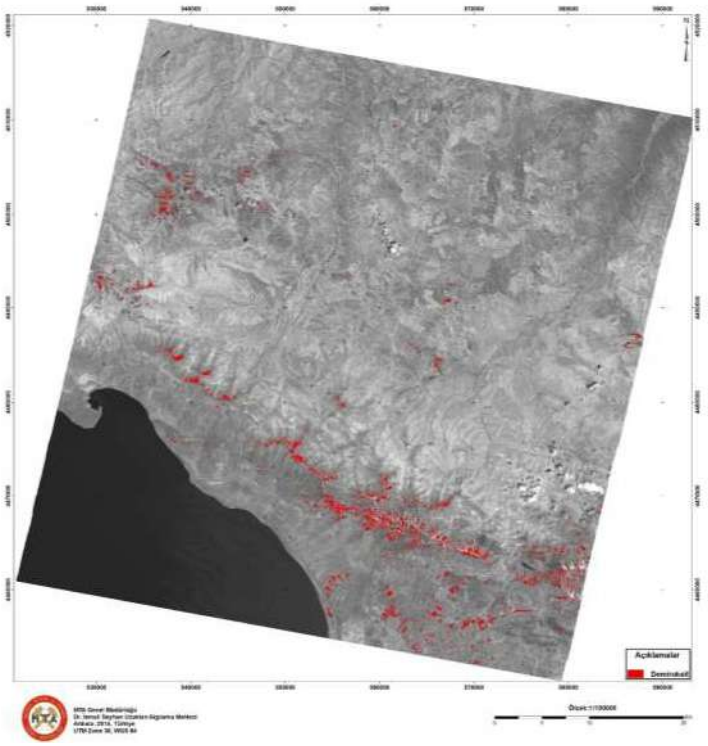

Fig. 6. The anomaly map related to iron oxide mineral in the Gadabay-Dashkesan area.

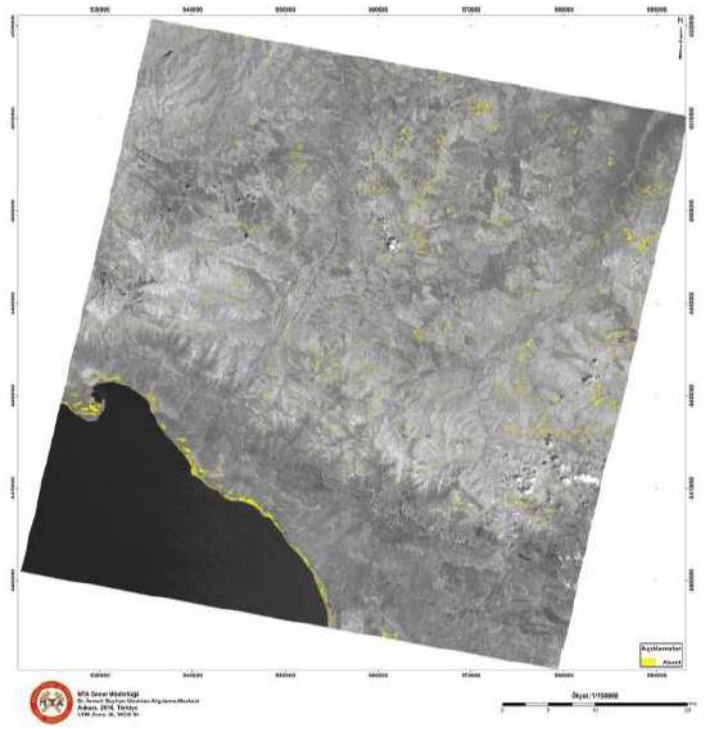

Fig. 7. The anomaly map related to the alunite mineral in the Gadabay-Dashkesan area.

The anomaly distribution related to the dolomite mineral has been observed in the north-south directions (Fig. 8). The dolomite anomalies with Mg characteristics restricted along the area are of great importance. The anomalies recorded in this area give us reason to think that they are sourced by the high amount of Mg in the content of rocks.

Fig. 8. The anomaly distribution map related to the dolomite mineral in the Gadabay- Murovdag area.

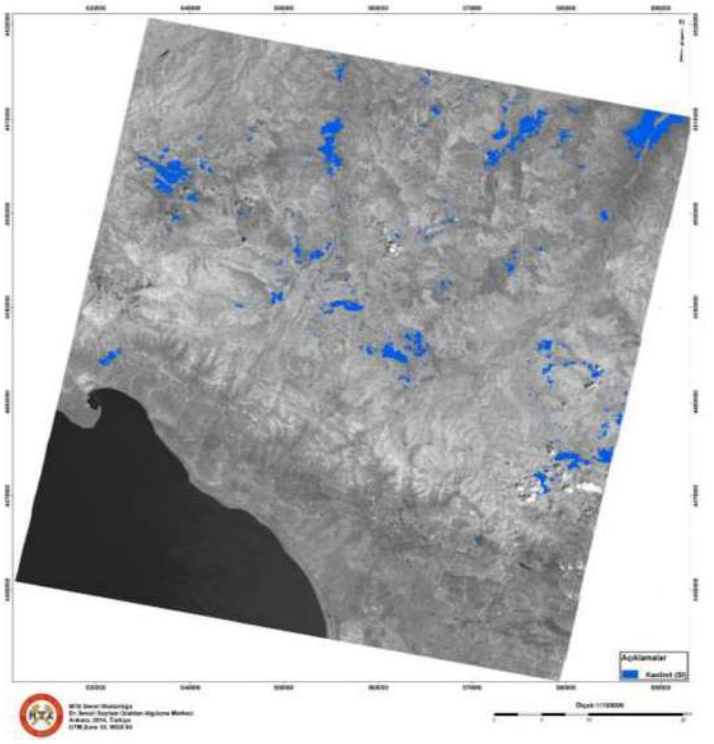

Fig. 9. Kaolinite mineral map obtained by spectral index method.

In the analysis made for the purpose of determining the distribution of calcite minerals by spectral index method, it was defined that calcite minerals are distributed approximately in the same spheres with band area (Abrams, 2000; Abrams et al, 2001). The density of the anomalies is observed more widely in the south of the area we have studied, particularly within the territory of Armenia. The distribution of this anomaly shown by us in the region is assumed to be sourced from limestone (Fig. 10).

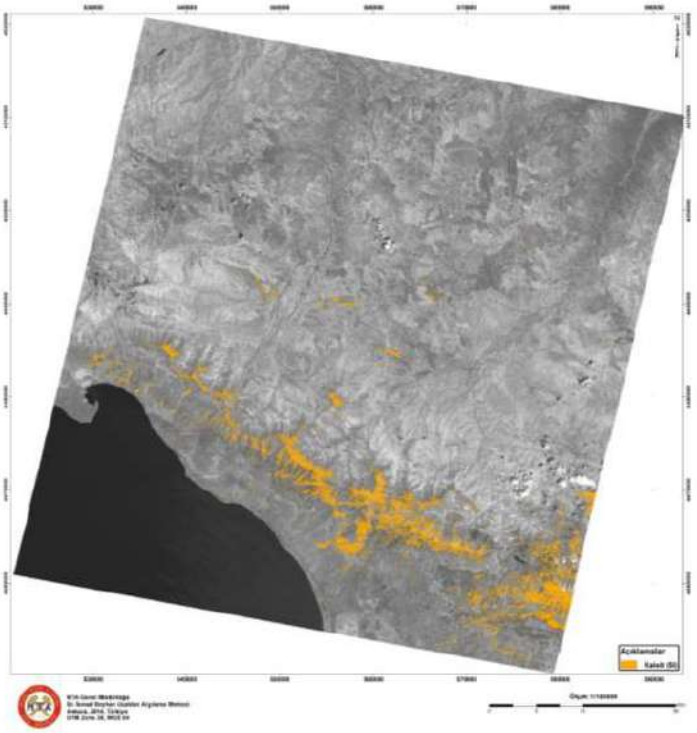

Fig. 10. Calcite mineral map obtained by spectral index method.

As known, like other alterations, the significance of kaolinite and alunite mineralization is great in definition of epithermal and hydrothermal ore deposits, in the planning of investigation work. The map was compiled on both revealed mineralization anomalies. As we can see, tight distribution is observed in many spheres on both distribution maps. The dense network of kaolinite anomaly limited in larger areas draws special attention here. Like other anomalies, these anomalies are followed up to Goyche Lake and its surroundings. But these anomalies can be false. It is assumed that the main cause of supposing these anomalies to be false can be sedimentogenous clay and kaolinite minerals which were left as a result of the lake drying up (Abrams, 2000; Abrams et al., 2001).

Allocation of prospective areas for field observations and testing work. For the purpose of studying the Gadabay ore district by remote-sensing method, the relevant territory has been divided into twelve squares with equal-area and each square has been studied individually. First, ASTER data was deciphered by relevant methods, ring and linear structures were allocated and being analyzed were classified in detail (Fig. 11). Later, on the basis of the panchromatic colours on the satellite images, the areas with vegetation cover of the territory, zones of mineralization and hydrothermal alterations were separated for their suitable colours (Crowley et al., 1989; Sabine, 1997; Gupta, 2003; Zhang and Panzer, 2007). On the basis of the acquired information, the sites characterized by hydrothermal alterations were allocated within each square. It is recommended to carry out geological observations and testing work at these sites and assess them from the point of view of prospects of mineralization.

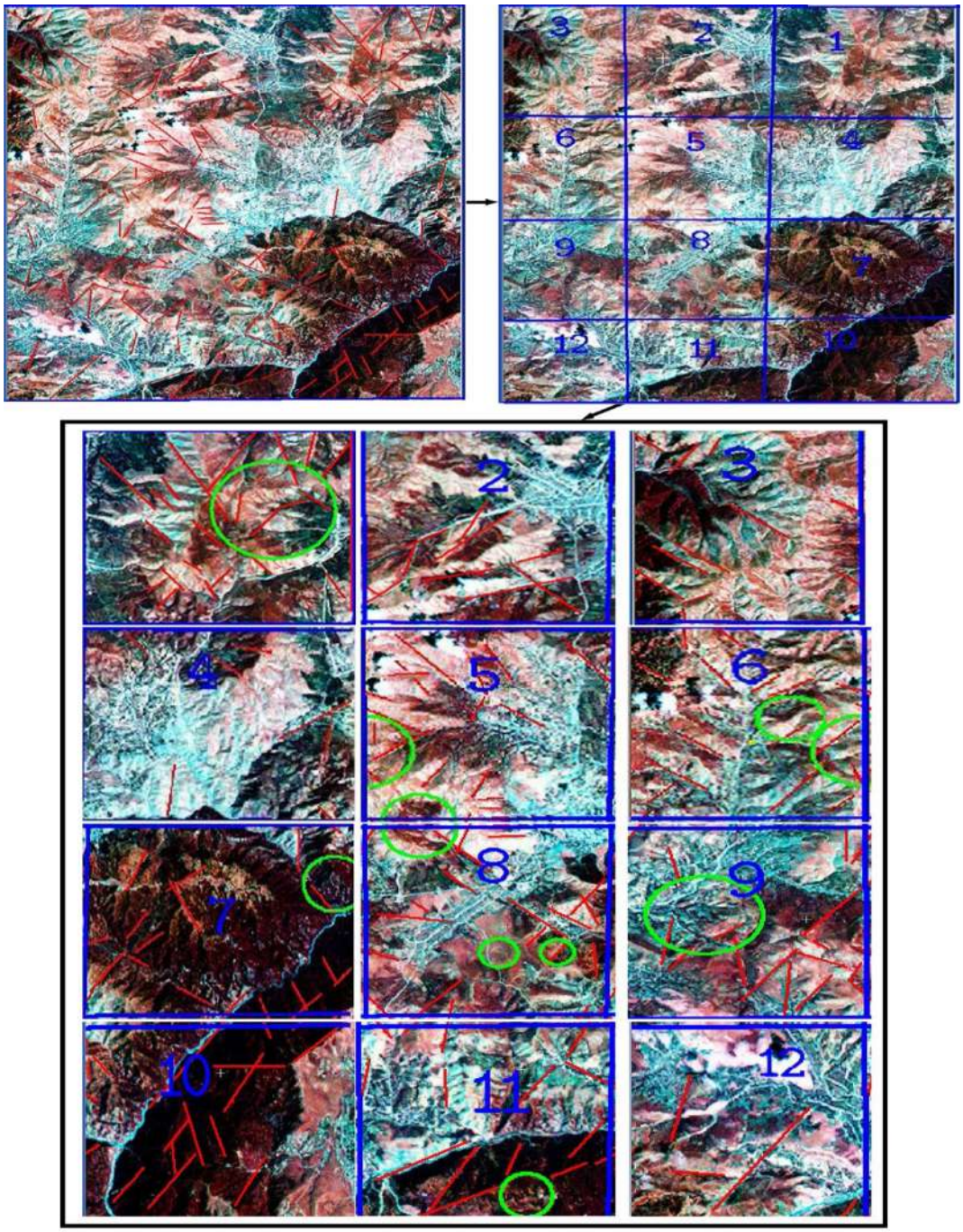

Fig. 11. The map – diagrams of lines and coloured structures Gadabay mine district

According to the analysis we have conducted on the basis of ASTER data, 37 potential hydrothermal alteration zones have been revealed through the Gadabay ore district. Seven areas among them were examined by geological exploration or investigation of the south-west of Misginli territory of Gadabay in the recorded zones № 27, 28 and 36, alteration and mineralization zones with dense network were observed (Fig. 12). At the sites of 1208141 numbers located within the zone № 28, andesites containing kaolinized and iron-oxidizing combinations occur. Pyrite, hematite, limonite and small-grained chalcopyrite mineralizations occur in the hydrothermal alteration zones accompanied by kaolinization and silification (Perry, 2004). The unmixing results from the ASTER reflectance data are very similar to the findings of other geological and mineralization studies in the same area (Willis, 1988; Durning et al., 1998; Babazade et al., 2018).

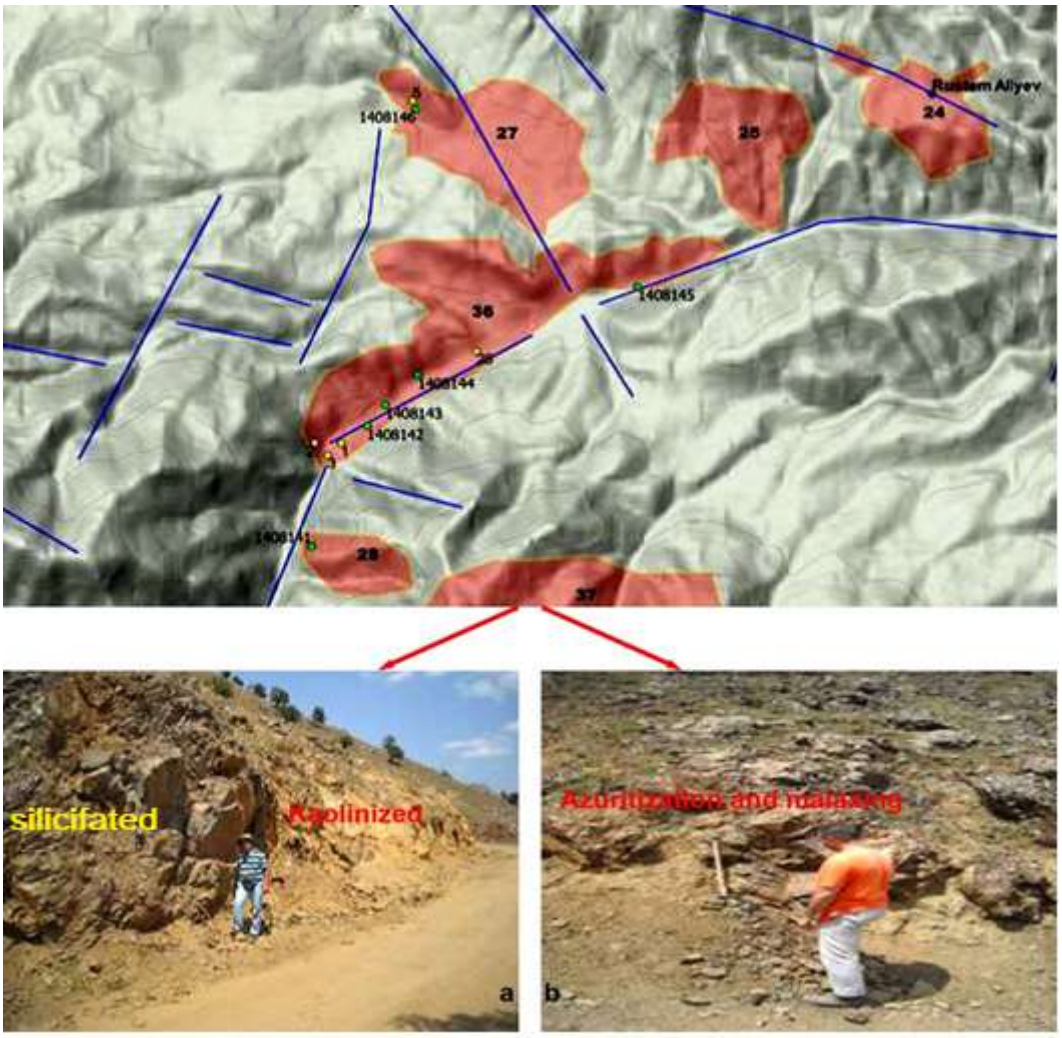

Fig. 12. Alteration zones along the territory in the areas № 27, 28 and 36 (1:55 000). a) silicifated and kaolinized zones NOTE in a "silicifated " should be in place of "silenced "; b)malachite and azurite mineralization observed together with silicifation.

Dense networks of hydrothermal alterations were traced in the same region, within the zone № 36, particularly in the area № 1408142. Here small-grained pyrite mineralization occurred within the areas of silicifated rocks with mafic property enriched in feldspar and cinnabaric minerals were found within red veinlets enriched in iron.

According to the results of ASTER image analysis at the site № 1408143 recorded within the same zone, hydrothermal alterations have developed extremely widely and kaolinization, tight iron-oxide anomalies and silification occur here. Small-grained pyrite minerals have been traced within the grey, brown silicifated zone. The other mineralization observed in the zone № 36 is the alteration zone enriched in malachite and azurite minerals. The observation of this mineralization is considered a significant indirect sign of search for discovery of copper-polymetallic, copper-porphyry and copper-pyrite type of mineralizations within the mentioned area. For this reason, it is recommended to carry out systematic testing work and conduct different (chemical, spectral and etc.) analysis within the region.

Samples have been obtained from 5 points along the Shamkir River, southwards, within the zone № 37 separated upstream of the Kukurdly Valley joining the Shamkir River from the left. Moving forward along the Shamkir River intensively altered and silicified andesites are observed in the area № 1608141. Alterations reflect dense pyrite phenocrysts, small amount of chalcopyrite mineralization. Associated with the alteration zones in the Kukurdly Valley in the south of the zone № 37 red ankeritolites ($CaCO_3FeCO_3$) are observed among brown limestones in the area № 1608142. For this reason, iron-oxide anomaly occurred in the region (Fig. 13).

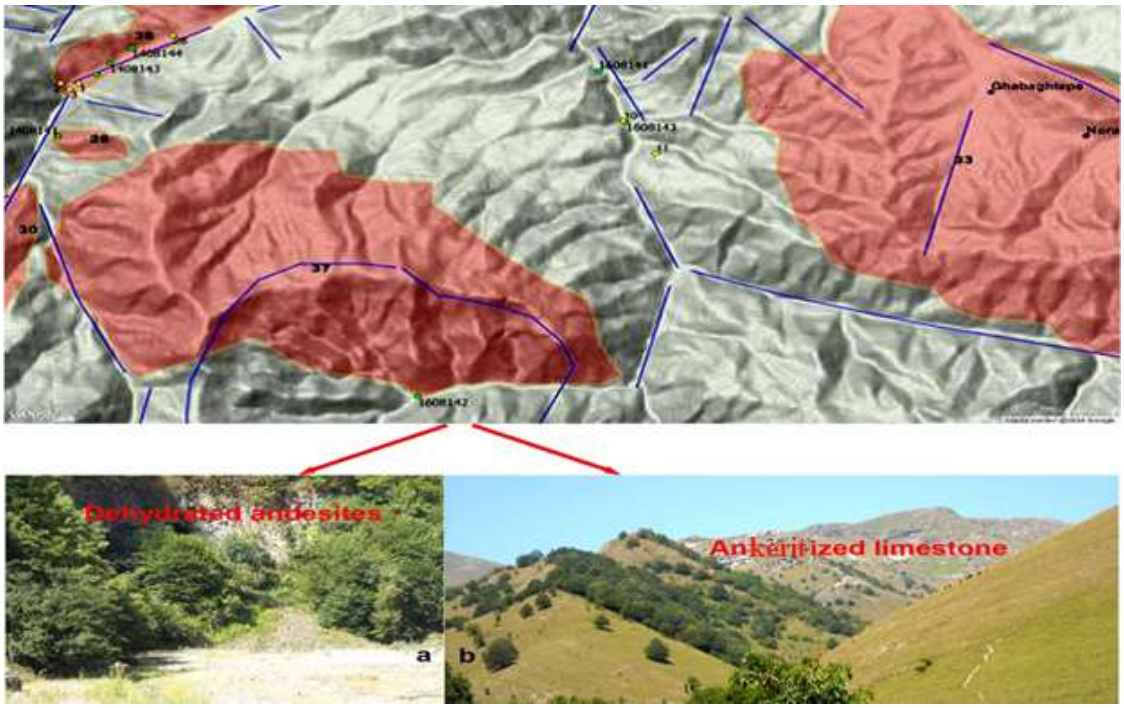

Fig. 13. The observation of silicified andesites (a) and ankeritized limestones (b) in Shamkir River and Kukurdly Valley zone (1:75000). NOTE in b Anchorized should be ankeritized

Based on the satellite data, the area has been registered where very frequent hydrothermal alterations (kaolinite, alunite, montmorillonite, sericite and etc.) and iron-oxide mineralization are observed within the zone № 9 recorded in the north-western part of the ASTER image of the territory (Figure14).

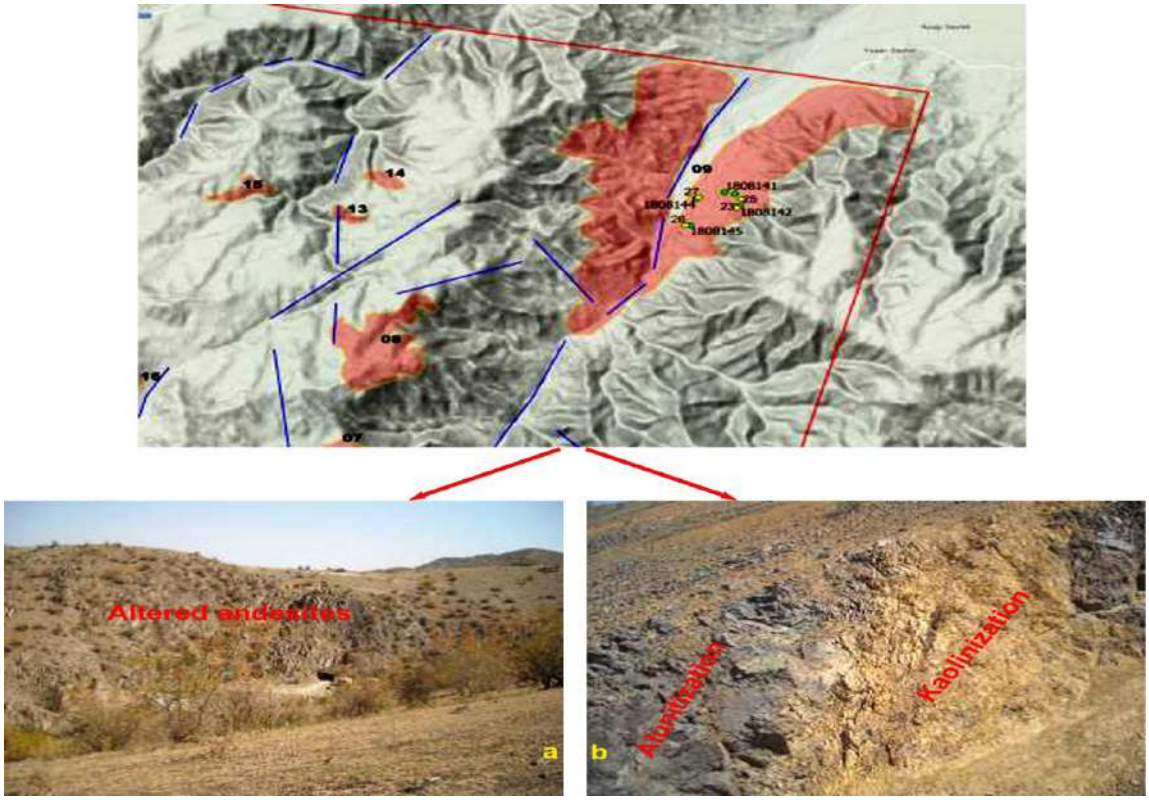

Fig. 14. The general view of kaolinized, silicified and altered andesites with abundant pyrite mineralization (a) and alunite, kaolinite mineralizations and silicifications within the zone № 9 located in the north-eastern part of the territory (Scale 1:100000).

As seen from the image, the region has been cut by a north-eastwards "free air"reduction. Along with widespread silicification, sericite, biotite, chlorite minerals, as well as mineralization of the oxidized zone exemplified by malachite and azurite occurred in the footprint area. Along with that, as a result of the information acquired by ASTER image analysis, the presence of minerals which is the product of hydrothermal alteration has been confirmed in the area.

At the site № 1808145 of the conducted research work, the areas characterised by kaolinization, alunitization, intensive hematitization and pyritization have been revealed within the rocks where hydrothermal alterations take place. Along with that, sometimes chalcopyrite mineralization was observed too. Here, wide observation of sulphide mineralization is a significant evidence for the search of epithermal ore deposits, the formation of which is supposed (expected) to exist in the region, and for making a systematic geochemical analysis.

By remote information and with the help of the relevant compiled anomaly maps, within separate areas, the points with special coordinates were allocated. These points are considered promising for geological research and testing from the point of view of intensity and types of hydrothermal alterations. The factors standing on the basis of the selection principles of this type of point are as follows: 1) the composition of rocks identified by comparison with remote-sensing data and other researchers' information; 2) according to the relevant analysis methods, based on the remote-sensing data, the detection of alteration zones; 3) intrusive mass, different-sized ring structures, different-sized fault fractures and lineaments in the territory, favourable areas for hydrothermal alterations and mineralization; 4) structure units, magmatic mass (intrusives, subvolcanoes, dykes, stocks, etc) defined on the basis of cosmic images and the existence of hydrothermal alteration zones accompanied by them.

Conclusions.

1. Based on the conducted research work, the conformity between the results obtained by ASTER image analysis and the conclusions drawn as a result of field work were confirmed.

2. Using stereoscopic images obtained from ASTER satellite data, existing or supposed tectonic structures in the region have been detected. These structures are considered to be significant from the point of view of defining potentially promising areas for mineralization.

3. The rock complexes cut by the tectonic structures have undergone various formational types of hydrothermal-metasomatic alterations and they are associated by different-type of mineralization.

4. Chalcopyrite, malachite, azurite, pyrite, cinnabar and the compounds of iron oxide accompanied by kaolinization, alunitization, silicification, sericitization, iron-oxidation and other hydrothermal alterations have been macroscopically defined in the discovered alteration zones. These mineralizations can be considered as probable sites for the localization of ores during prospecting and evaluation works.

5. The zones of hydrothermal alteration mentioned in the region are significant from the point of view of mineralization. The presence of high sulphide mineralization in the area creates conditions for carrying out complex geological-mineralogical work systematically in order to detect ore deposits in the region in future.

6. The experience of the conducted work shows that the application of ASTER data allows us to allocate potentially promising areas for the mineralization in the initial stage of the geological-exploration process and it reduces the cost of the exploration work of the ore minerals in the region.

Conflict of Interest

The authors state that they are not involved in any conflict of interest.

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Conditions of localization and patterns of distribution of gold-poly-metal mineralization of the Dagkesaman deposits (Lesser Caucasus, Azerbaijan)

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Abstract. We studied the structural-morphological types and mineral composition of ore bodies, stages of ore development and conditions of development of the deposits. The research revealed significant elements of the corresponding conditions of localization of gold-polymetallic mineralization, the most characteristic being albitophyre subvolcanic bodies and steeply-dipping damages related to them. According to the structural-morphologic peculiarities, the ore bodies should be united under three categories: 1) simple vein; 2) complex vein; 3) veinlet-impregnation types. The positions of gold ore bodies and their morphological peculiarities were found to be determined by structural factors. Presence of small ruptures, differently-oriented systems of fractures and faults, which run across the area, gentle curves of these systems and other structural elements –all of this promotes gold ore development. There research determined aureoles of ore-containing altered rocks (serialization, chloritization, kaolization and calcinations, and limonitization from hypergenical zones) and presence of zonal structure. Gold-productive areas were identified as the quartz-pyrite association with disperse gold, and especially, the second mineral association where there is a notable close paragenetic connection between noticeable gold and chalcopyrite-galena parageneis of polymetallic stage. In the process of ore development, the physical-chemical conditions have presumably changed from average deep (quartz-pyrite-sericite) to shallow (quartz-galena- sphalerite-gold ore) and close-to-the-surface (quartz-chalcocite-hematite). Gold that occurs with all the mentioned minerals of this stage has developed in the temperature interval of 220–160 °C. The study found the ores to be complex, containing the following dditional elements: Fe, Cu, S, Bi, Zn, Pb, As, Se, Te. The main fossil component is gold. Industrially valuable are also cadmium, zink, copper and silver, found in the ores. We found the following morphological types of grains of native gold: homogenous, zonal, mono-granular, spotted, which are of great significance for concluding on genesis of the deposits, prognoses, explorations and assessments.

Keywords: Dagkesaman, gold-polymetallic, structural-morphological, sulfides, gold mineralization, ore development

Умови локалізації та закономірності розміщення золото-поліметалічного зруденіння Дагкесаманского родовища (Малий Кавказ, Азербайджан)

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Анотація. Досліджено структурно-морфологічні типи та мінеральний склад рудних тіл, стадийність рудоутворення і умови формування родовища. Виділено суттєві елементи відповідних умов локалізації золото-поліметалічної мінералізації, найбільш характерними серед яких є альбітофірові субвулканичні тіла і крутопадаючі пов'язані порушення. За структурно-морфологічними особливостями рудні тіла були об'єднані в три групи: 1) прості жильні; 2) складні жильні; 3) прожілково-вкраплені. Встановлено, що позиції золоторудних тіл і їх морфологічні особливості визначаються структурними чинниками. Наявність дрібних розривів, перетин різноспрямованих систем тріщинуватості і розривів, пологі вигини останніх і інші структурні елементи – все це сприяє локалізації золотого зруденіння. Було встановлено ореоли рудовміщуючих змінених порід (серіцітізація, хлорітізаціі, каолінізація і кальцітізація, з гіпергенних змін – лімонітізація), наявність зональної будови. Встановлено, що продуктивною на золото є кварц-піритова асоціація з дисперсним золотом і, особливо, друга мінеральна асоціація, у якій підкреслюється тісний парагенетичних зв'язок гіпогенних видимого золота з халькопирит-галенітовим парагенезісом поліметалічної стадії. Висловлено припущення, що в процесі рудоутворення фізико-хімічні умови змінювалися від середньоглибинних (кварц-пірит-серіцітових) до малоглибинних (кварц-галеніт-сфалерит-золоторудних) та близькоповерхневих (кварц-халькозин-гематитових). Золото, що зустрічається з усіма згаданими мінералами цієї стадії. утворилося в температурному інтервалі 220–160 °С. Виявлено, що руди полікомпонентні. Визначено елементи-домішки: Fe, Cu, S, Bi, Zn, Pb, As, Se, Te. Основним корисним компонентам є золото. Промислове значення в рудах мають також свинець, цинк, мідь і срібло. Виявлено наступні морфологічні типи зерен самородної золота: однорідне, зональне, монозернисте, плямисте, які мають велике практичне значення для з'ясування генезису родовища, прогнозних і пошуково-оціночних робіт.

Ключові слова: Дагкесаман, золото-поліметалічний, структурно-морфологічний, сульфіди, золота мінералізація, рудоутворення.

Introduction.

The epithermal high sulfidation deposits of Dagkesaman contain some of the country`s main deposits, located in the Kazakh ore district (Azerbaujan), and promising deposits of epithermal gold polymetallic ores. These deposits belong to the Lesser Caucasus, lying in the central part of the Tetis metallogenic belt (Fig. 1). Deposits are in the Jurassic-Cretaceous Lok-Karabakh magmatic arch, developed as a result of the subduction of the Neo-Tethys Ocean along the outskirts of Eurasia (Geology of Azerbaijan, 2005).

The Kazakh ore district within the Lesser Caucasus, which includes the Dagkesaman deposits, is of great interest for discovering gold polymetallic ores, as indicated by the presence of areas containing polymetallic gold ores and individual manifestations of ores. The tectonic position of the deposits is confined to the Kazak transversal depression in the western segment of the Lok-Karabakh island arc (Geology of Azerbaijan, 2005). The deposits were studied from the surface to the depth of 300 m in numerous wells and mining works.

The main objectives of the study were the conditions of localization and patterns of the Dagkesaman polymetallic gold ore deposits and the possibility of reconsideration of the perspective of its future exploration.

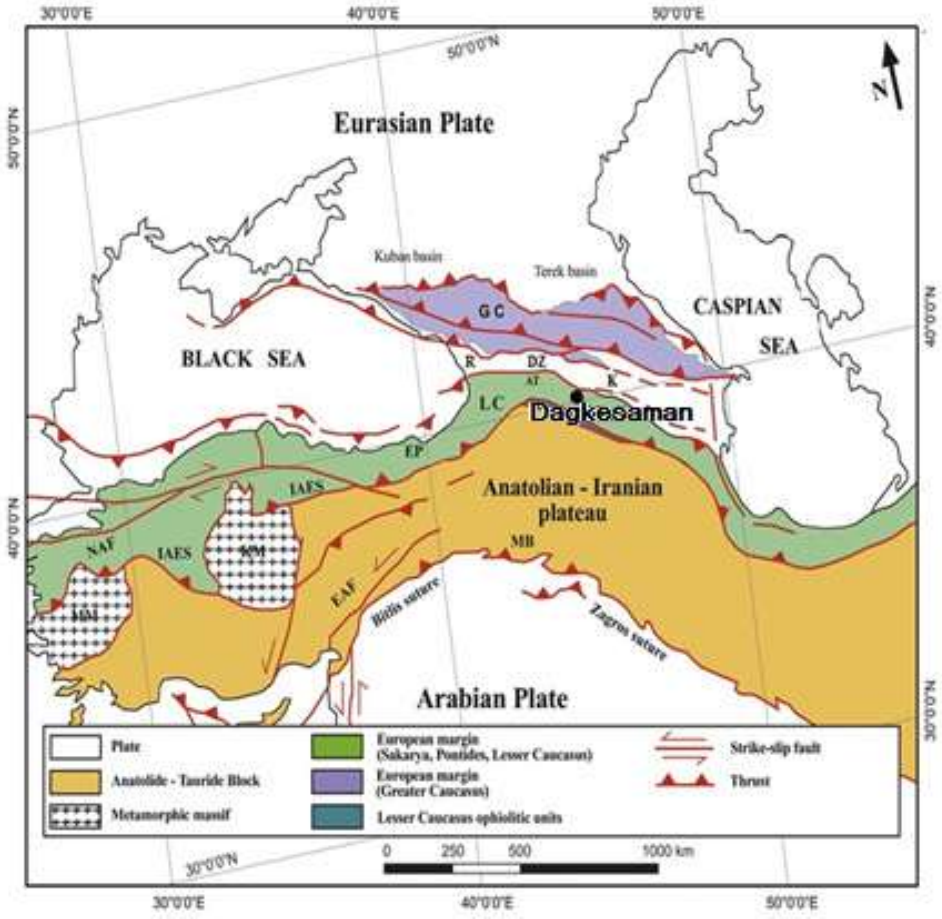

Fig. 1. Tectonic map of the zone of Arabia-Eurasia collision. Location of the Dagkesaman deposits is shown by circle (Sosson et al. 2010). Сокращения: GC-Greater Caucasus; LC–Lesser Caucasus; AT- Adjara-Trialeti; R- Rioni; Dz-Dzirula; K-Kura; MB – Mus basin; EP – Eastern Pontides; KM – Kırşehir Massif; EAF – Eastern Anatolia Fault; NAF – North-Anatolia fault;; IAES- İzmir – Ankara-Erzincan suture; MM–Menderes Massif.

Materials and methods.

The tasks were solved using the materials mainly collected by the authors personally during the study of the ore field and deposits. The basis for the structural studies in the ore fields and deposits were the data of detailed mapping of the surface, carried out in the scales of 1:2,000 and 1:5,000, documents of underground mining and core samples of the wells. We performed lithologic-petrographic studies of ore-containing rocks and formation analysis of magmatic complexes.

In the study of samples of rocks and ores, we used optical microscopy, scanning electron microscopy and X-ray-spectral microanalysis.

Mineralogical composition of the ores and chemical composition of ore and non-ore minerals were analyzed using modern special instrumental mineralogical operation system QEMSCAN™, with application of electrone microscope, x-ray-fluorescent analisys and microspectral sensing. Silicate chemical analysis was conducted in the laboratory of İzmir University, Turkey.

To develop graphic illustrations, we used software Corel Draw Graphics Suite, Surfer, ArcGIS.

Specifics of geological structure of the deposits. The deposits are located within the contour of the ore field of the same name in the eastern part of the Kazakh ore-bearing district. Ore-containing rocks are of volcanogenic basalt-andesite-rhyolite formation of Cenomanian-Upper Santonian (Abdullaev et al., 1988). Within the borders of the deposits, only the Upper Turonian-Lower Coniacian layer is exposed, which is 800 m thick and represented by lavas of andesites and andesite-dacites alternating with tufa, making up the elevated tectonic block. It is this layer that contains ores of the Dagkesaman deposits (Fig. 2). Within the borders of the deposits, the thickness of lava flows and the layers of tufa which divide it varies 20 to 100 m. According to the data of the wells, the lava flows and tufa layers are distributed down to 450 m depth. Ore-containing rocks are torn by numerous large dikes, rarer diabases that are subvolcanic facies of the same series of andesite-basalts (Abdullaev et al., 1988).

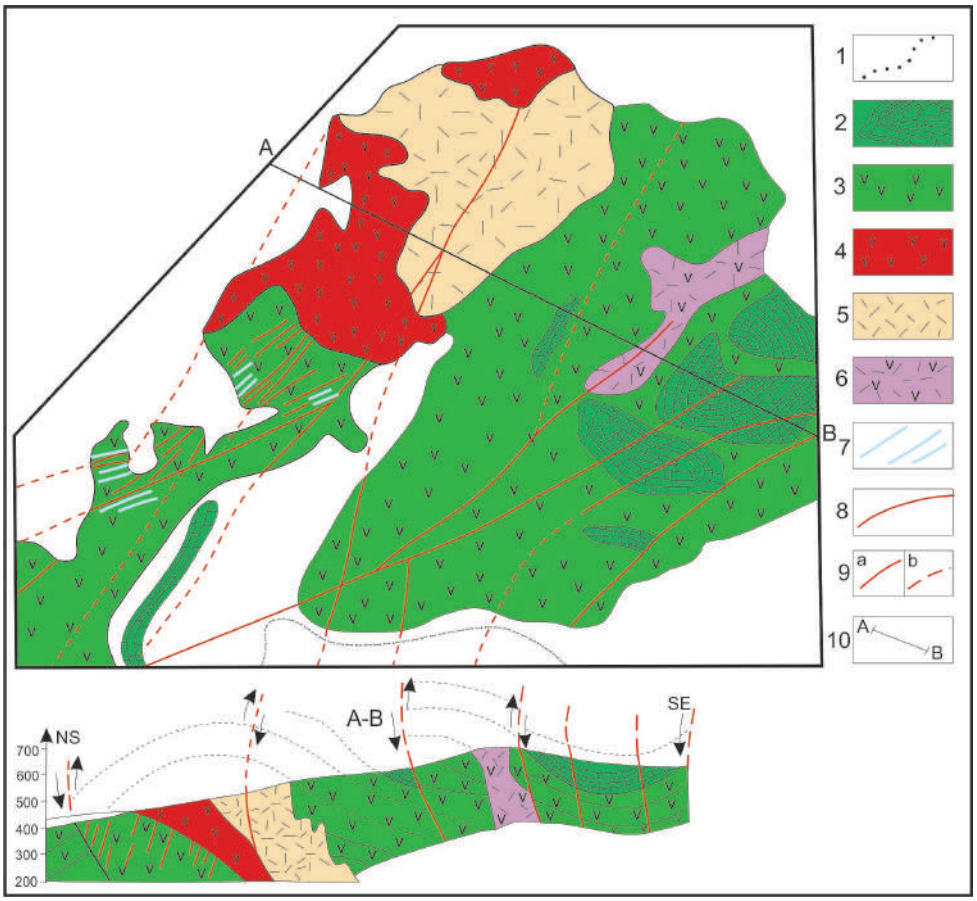

Fig. 2. Geological map of the Dagkesaman gold-poly metal deposits: 1 – current deposits, 2 – pelitomorphic limestone, 3 – volcanogenic sedimentary rocks, 4 – albitophyres, 5 – dacite, 6 – andesite-dolerite, 7 – andesite-dolerite dikes, 8 – hydrothermally-altered ore zones, 9 – faults: a) determined, b) assumed, 10 – cut along the A-B line.

The Dagkesaman deposits are confined to the conjunction of two mutually perpendicular structures notable at the basement and Alpine story by the zones of heightened fractures and foliations limiting the flat-parallel blocks of various sizes and amplitudes of movements, different in the degrees of dislocations and metamorphism, concentration of ores and magmatism. At the same time, there are important transversal dips, dip shifts as the main structures of the ore-magmatic systems that contain the major amounts of ores of various types (Baba-zade et al., 2015).

Within the deposits, the ore-containing faults unite into three groups: western, central and eastern. Each group includes four to eight subparallel ore-containing faults that separate the belt structure of dikes of diabases and zones of sulfide mineralization.

Structural-morphological types of ore bodies. Structural-morphological types of ore bodies may be united into three main groups: 1) simple veins; 2) complex veins; 3) veinlet-impregnation types (Baba-zade et al., 2006). Simple vein bodies usually have quartzitic and quartz-chalcedony compositions, notable development of simple linear forms, have no apophysis and distinct vein walls. Such veins are mainly confined to the fractures of two strike systems (60–65°and 230–300°). They are characterized by steep, often near-the-vertical dip angles (75–85°), small amount of them have less steep dip (50–60°), mostly 100–150 to 500 m long and vary more in thickness, 10–15 m (rarely 20 m and more) in places of upswell and 0.5–0.7 m in places of contraction.

Vein bodies of complex structures are most notable for ores of quartz-carbonate composition, accompanied by thin and short feathering veins and veinlets, located on both vein walls. Similarly to the quartzitic veins, they have distinct contacts, short strike and thickness equaling 50–150 m and 0.3–0.6 m respectively (Fig.3). Veins of this type usually pinch out on small distances and ramify in accordance with the form of tectonic fractures. Such veins often have en echelon structure, sometimes being combinations of numerous differently-oriented thin (0.1 m) veinlets.

Veinlet-impregnation type of ore-bearing bodies is represented by the zones of fracturing of sulphidized metasomatically-altered volcanogenic rocks that contain quartz and carbonate-quartz veinlets. By their structure, such zones are close to vein bodies of complex structure, but have greater length (100–500 m) and thickness (50–150 m). Due to the development of metasomatic processes in these zones, there are no distinct contacts with the containing rocks.

Most of gold ore veins and zones are characterized by steep, often close-to-vertical (75–85°) dip; small amount of them have less steep embedding reaching 50–60°.

Positions of gold ore bodies and their morphological peculiarities are determined by structural factors. The presence of small feathering faults, differently-oriented systems of fractures and faults which run across the area, gentle curves of these systems and other structural elements – all this promotes localization of gold mineralization. Taking into account that the main ore-bearing zones of deposits are located within the anticline fold and are related to the steeply dipping faults that cross a thick complex of effusive-pyroclastic formations, the localization of strata-like ore seeps in porous pyroclastic rocks directly under covering formations is quite possible (Baba-zade et al, 2006).

Specifics of structural-morphological typization of ore bodies and deposits are determined by their configuration and pattern of sequence of changes with depth. This pattern reflects the direct dependence of the structure and morphology on the relationships with the types of magmatic and metasomatic rocks.

Metasomatic changes in the containing rocks. In the ore zones, the lateral rocks are the ones mostly intensely subjected to various changes in the places where they are represented by andesite porphyrites and their pyroclastolites. The most intensely manifested process is the silicification, reaching the transition of volcanogenic rocks into secondary quartzites and formations similar to them, which have developed around the ore zones, equaling 10–15 m in width. Sericitization, chloritization, kaolization and calcitation, and of hypergenic changes – limonitization are also common in the area. The oreols of altered ore-containing have a zonal structure. The internal zone of kaolinization changes to the periphery by poorly chloritized rocks without notable sulfide mineralization. Sericite, closely related to the process of silicification, develops as scales and sheets between the grains of quartz, sometimes developing individual accumulations there. Kaolinization, particularly chloritization and carbonatization, has a limited development in the zones of ore localization (Baba-zade et al., 2006; Baba-zade et al., 2015).

Gold, silver and sulfides associated with them are a part of the metasomatism process. Analysis of the data from the wells (№№ 2, 7, 60, 61, 41, 102, 17, 35 and others) and mining works (mine № 8, mine № 1) indicates that formations near the ore and solfataric facies of secondary quartzites contain gold (0.2–0.7 g/T) (Table 1), and the content of it increases toward the ore zones and quartz-sulfide veins.

Table 1. Chemical-spectral composition of metasomatites of the Dagkesaman deposits

Types of metasomatic rocks	Number of samples	Content of elements				
		Au, g/T	Ag, g/T	Pb,%	Zn,%	Cu,%
Mono-quartzous	14	0.25	6.6	0.12	0.4	0.12
kaolinitic	30	0.22	2.66	0.13	0.31	0.06
chloritic	10	0.3	1.6	0.14	0.6	0.3
Near-ore	70	0.7	2.8	0.10	0.25	0.04

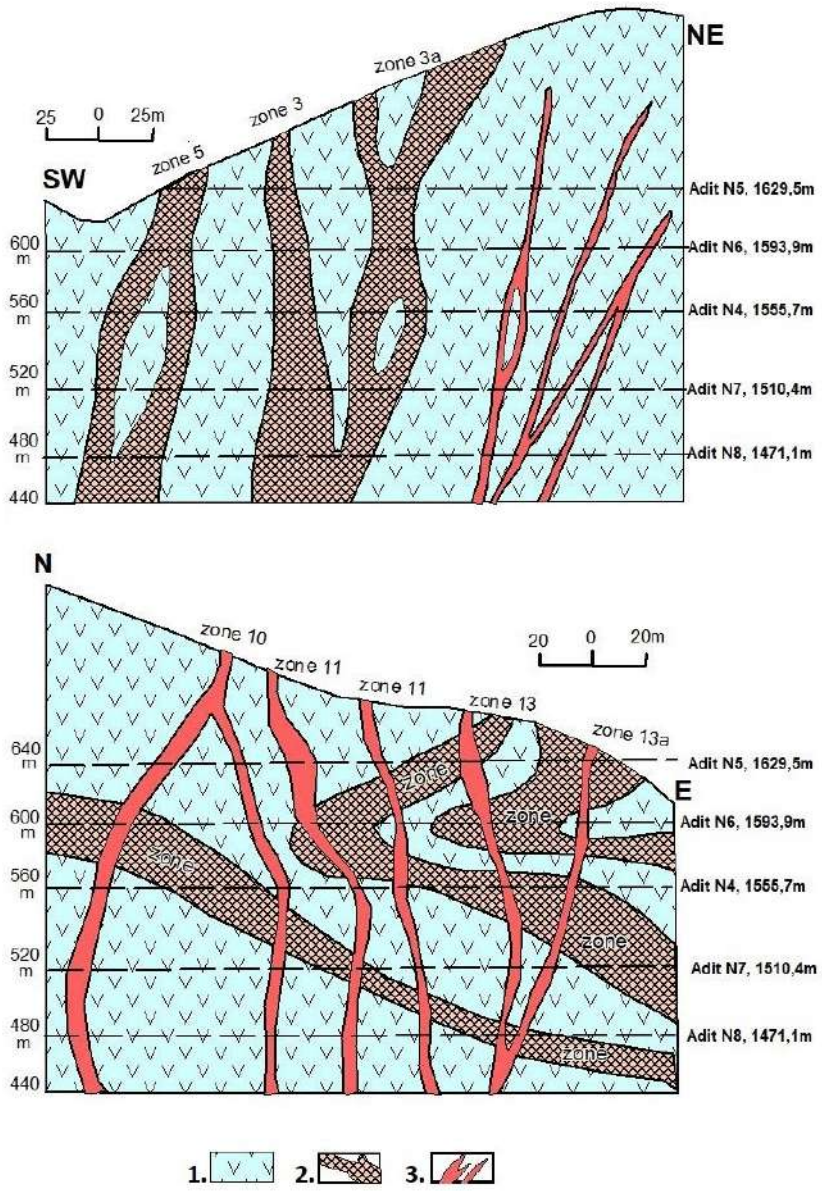

Fig. 3. Structure of ore bodies of the Dagkesaman gold-poly metal deposits: 1 – andesites, 2 – mineralized and vein zones with gold, 3 – quartzous veins and interveins with gold mineralization.

Mineral composition of ore bodies. Analysis of the data on mineralogy and issues of stages of ore-development of Dagkesaman deposits was carried out using the results of the earlier studies (Baba-zade et al., 2006; Baba-zade et al., 2015) together with our own observations and additions.

The Dagkesaman deposits of the ore basin are characterized by great variability of mineralogical composition, structures and textures of the ores. About 30 minerals were determined in the ores. The main ore minerals are represented by pyrites, sphalerites, chalcopyrites and galenas. The secondary minerals are melnikovites, marcasites, native gold and silver, hematite, polybasite, rutile, magnetite, bornite and other. Vein minerals are represented by quartz, carbonates, barite, chlorite, sericite and muscovite (Baba-zade et al., 2006).

The study of interrelations between the minerals (Ramdor, 1962) allowed us to designate 3 generations of pyrite, chalcopyrite and sphalerite. Generations of pyrite and sphalerite were designated according to the interrelations with chalcopyrite: chalcopyrite appears as cutting veinlets, replacing pyrite-I and sphalerite-I, the borders of its aggregates and grains with pyrite-II and sphalerite-II are even, without corrosive interrelations.

Pyrite-I occurs as impregnations, nest-type thin and short veinlets, characterized by two types. Pyrite-I of average-grained structure comprises shapeless and cubic crystals sized 0.02–0.05 to 2 mm (Fig.4a). The second type of pyrite-II is cubic and pentagonal dodecahedron with allotriomorphic-granular structure and forms relatively large aggregates sized 5–6 mm (Fig. 3b) against the background of fine-grained py-

rite. Both kinds of pyrite are characterized by uneven distribution, corrosion, brecciation, being crossed by late sulfides. Pyrite-III forms well notable cubic, hexagonal crystals sized 0.05–0.08 mm.

Chalcopyrite-I occurs as small spotty accumulations sized 0.02–0.03 to 0.2–1 mm (Fig. 4 c-d) in the interstitia of pyrite-I. In the largest grains of chalcopyrite-I, there were seen micro-inclusions of sphalerite-I (decomposition of solid solution), indicating high-temperature regime of their development. In association with pyrite-II, sphalerite-II and galena-I, chalcopyrite-II forms spotty and nest-type accumulations (Fig.4e-f). Its crystals are almost isometric and irregular in shape, sized 0.5–0.1 to 0.2–1 mm, and form structures of mutual strikes with sphalerite-II and galena-I without signs of replacements. Chalcopyrite-III is quite common. Grains sized 0.05–0.08 mm are in associations with galena-II and gold-II.

Sphalerite-I is seen as small bodies sized 0.04–0.08 mm. Sphalerite-I in associations with chalcopyrite-I fills the spaces between the grains of pyrite-I, replacing and corroding it. The grains of sphalerite-I often form bud-like concentrations. Sphalerite-II is distinct by large (1–8 mm) sizes of grains. In association with galena-I, it forms impregnated, spotty and nest-type concentrations.

Galena-I occurs as small plate-like bodies in associations with chalcopyrite (Fig. 4g). Irregular-shaped aggregates are developed extremely unevenly. Sphalerite-II and chalcopyrite-II are closely grown together without signs of replacement.

Molybdenite occurs quite rarely. Elongated plate-like specimens sized 0.005–0.01 mm are associated with late quartz (Fig.4h).

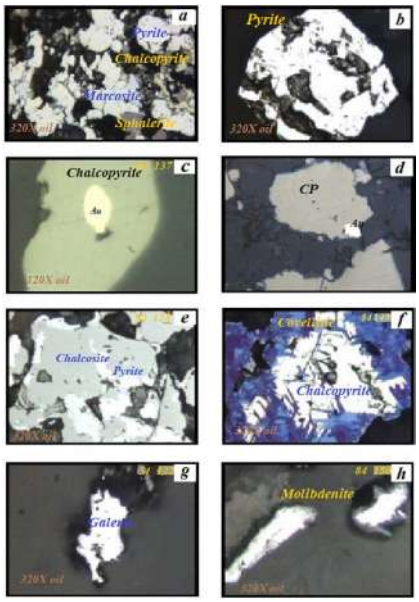

Fig. 4. Fragments of photomicrographic mineralization on Dagkesaman deposits: a-pyrite of average-grained structure, b-cubic shape of pyrite, c-d-chalcopyrite of generation I, e-f-spotty and nest-type accumulations of chalcopyrite, g – plate-type bodies of galena, h-elongated plate-like bodies of molybdenite.

Native gold occurs mostly as veins of collomorphic zonal structure with small xenolithes of containing rocks. Numerous signs (81) of native gold which were found in one of polished section are confined mainly to the stripe before the vein wall of quartz. Under the microscope, gold is seen also in pyrite, sphalerite galena and chalcopyrite; it forms scale-like concentrations in the initial sulfide ores as stripes and spots (Fig. 5). The color of gold is mostly saturated bright yellow, but there brighter grains of yellow color also occur. The shape of gold completely depends on the regions of fractures and small pores it had filled. Size of the bodies varies 0.001–0.05 to 1 mm, rarely larger. The commonest forms of gold are plate-like, dust-like, sheet-like, and also drop-like and irregular-shaped bodies (Peterovskaia et al., 1976; Akhmedov et al., 2019).

Silver, which was found in the sample of oxidized ores, is represented by several mineral forms, including: free, Au-Ag alloy and rare minerals – jalpaite and stromeyerite. All these substances such as gold are represented by small grains, closely associating mainly with iron oxides (Guseynov, 2019).

Native silver and its minerals in oxidized ores (13 elements) were mainly found in oxides of Fe-Ti and only 3 elements were identified in light fraction (Fig. 6). This indicates that large amount of silver in oxidized ores is closely associated with iron oxides and hydroxides. The identified elements of silver are represented by small grains of 1–8 μm, 5 μm on average. By chemical

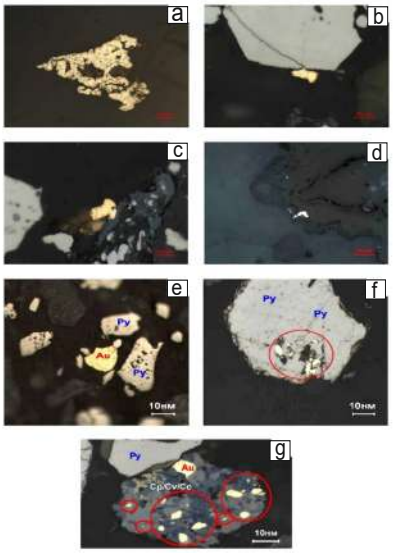

Fig. 5. Photos of gold grains in sample of oxidated ore (Сомр. A): a – large free and partly porous gold, b – free grain near pyrite (Py), c – confined to covellite (CV) and dark (unidentified) minerals (NOP), d – free (indicated by red) confined to dark (unidentified) minerals in primary sulfide ores, e – native gold, f – inclusions in pyrite (Py), g – inclusions in chalcopyrite (covellite, chalcocite) (Cp/Cy/Cc).

composition, determined using x-ray microanalyzer, 4 grains were characterized as native silver (Ag>90 %), 9 grains were Ag-Cu alloy (Ag>60 %, Cu to 40 %). Furthermore, rarely occurring silver-bearing minerals were found, two of which were characterized as jalpaite (Ag-55,7 %; Cu-29,7 %; S-14,5 %), and one as stromeyerite with contents in%: Ag-55,1; Cu-28,6; S-16,3 (Guseynov et al., 2103; Guseynov, 2019).

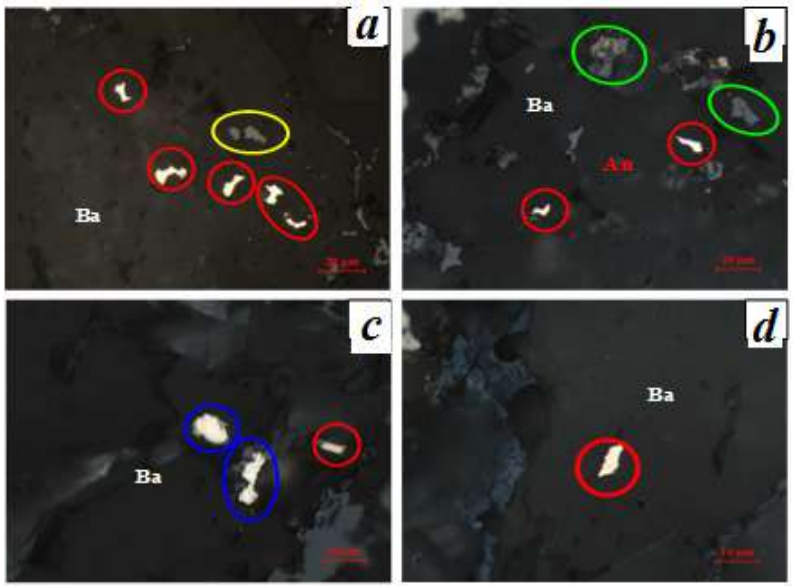

Fig. 6. Microphoto of grains of silver in oxidezed ores (inclusions in barite and in association with barite): a-mixture of Cu-Ag alloy (in red circles) and stromeyerite (yellow circles); b-mixture of Cu-Ag (in red crcles) and jalpaite (in green circles), c- mixture of Cu-Ag (in red circle) and native silver (blue circle), d- mixture of Cu-Ag (in red circle).

As known, the quantitative relationships between gold and silver in ores may serve as indicators of processes of development of minerals and migration ability of silver and gold (Vikinteyev, 2006). Practical significance of Au: Ag is used in finding elements of hypogenic zonality in some cases, and in assessing ore bodies in depth in other cases. Within the deposits, the value of this relationship varies and changes with depth differently. We studied and determined the patterns of changes of relationship between gold and silver from the surface down to 340 m depth. For this purpose, we made around 600 analyses of gold and silver from ore zones and their containing rocks from various adit horizons (Table 2).

Table 2. Distribution of contents of Au, Ag and values of their relations in the containing rocks and ore deposits (in the horizons of adits)

Horizons of adit	Containing rocks and ores	Number of analysis	Elements		Au: Ag
			Au	Ag	
Adit № 2 (562.2m)	containing	80	0.005–4.0	0.0–26.0	1:12
			0.14 (32.6)	1.2(17.1)	
	Ore deposits	95	0.005–4.3	0.0–72.0	1:4
			1.2 (279.0)	2.9 (41.4)	
Adit № 3 (535.4m)	Containing	90	0.005–9.0	0.005–37.0	1:6
			0.18 (41.8)	1.13 (16.1)	
	Ore deposits	100	0.005–77.0	0.005–212.5	1:4
			1.5 (348.8)	3.54 (50.5)	
Adit № 8 (411.8m)	Containing	100	0.0–1.6	0.0–13.2	1:12
			0.12 (27.9)	1.6 (22.8)	
	Ore deposits	125	0.0–46.4	0.0–86.0	1:3
			3.8 (883.7)	16.0 (228.0)	

Note: in numerator – variation of contents of elements, in denominator – average content, in brackets – clarke of concentrations

The impregnations, striped, veinlet, spotty, massive and brecia textures are distributed in the ores. There rarely occurs cockade texture, which develops in the areas of growth on the fragments of altered rocks and significantly sulfide ores of chalcedony quartz, associated with calcite. Of the ores, we should note granular (allo-and hypidiomorphic), skeletal, loopy and cementing ones (Akhmedov et al., 2019).

Results and discussion.

Mineralogical analysis of ores of Dagkesaman deposits revealed that the development of gold polymetallic mineralization was relatively long and occurred in several stages. Based on the obtained geological-structural data and the study of ores and their texture-structural specifics, there are the following stages of mineral formation (Baba-zade et al., 2006; Baba-zade et al., 2015): I – stages of deposition of the main mass of quartz, and then quartz-pyrite-sericite mineral association II – quartz-galena-sphalerite-gold (polymetallic) ore stage, including quartz-pyrite, sphalerite-chalcopyrite-pyrite, gold-chalcopyrite-galena, quartz-hematite-magnetite and quartz-carbonate associations.

The research found two productive, subsequently developed mineral associations: quartz-pyrite with disperse gold and gold-chalcopyrite-galena, divided by tectonic movements. Gold-bearing pyrite of early association has catalized to various degrees – from small fractures to small fragments and has been cemented by minerals and poly-sulfide association, which are closely grown together (Volkov et al., 2018).

At the hypergenic stage, minerals of oxidation zone (measuring mostly 20–25 m, sometimes reaching 30–40 m) as well as zones of secondary enrichment (covellite, argentite, polybasite, stromeyerite, jalpaite and others) are developed in the deposits. At the same time, high concentration of gold in ore zones of oxidation is connected with secondary hypergenic processes (Roslyakov, 1991). Fine-disperse gold (1–10 μ) occurs as catenate, ameboid bodies. At the same time, native gold is average and fine (90–97 weight.%), silver –5.6 to 33.1 weight.% (Guseynov, 2019). Additional elements are Fe, Cu, S, Bi, Zn, Pb, As, Se, Te. Gold fineness varied broadly (800 to 950 ‰). The following morphology of grains of native gold was identified: homogenous, zonal, mono-grained, spotty. Sometimes, there are crystals of native gold which are represented by octahedrons. These internal structures of native gold are of great practical significance during analysis of genesis of deposits, making predictions, surveys and assessments (Guseynov et al., 2013).

Gold-productive is quartz-pyrite association with disperse gold and, specifically the second mineral association with a close paragenetic relationship between hypogenic noticeable gold and chalcopyrite-galena paragenesis of polymetal stage. Ubiquitous distribution of quartz-pyrite mineral association with thin-disperse gold in the ore zones creates background contents of gold in the deposits, and its increased amounts are confined to the areas of presence of chalcopyrite-galena mineral association with native gold. The contents of silver in ores increase with presence of gold and silver-containing pyrite and chalcopyrite, sometimes with galena (Table 3).

Table 3. Chemical composition of some sulfides of the Dagkesaman deposits.

Minerals	№ sample	Content, weight%									Total	Formula
		Fe	Cu	As	Ag	Au	Zn	Te	Co	S		
Pyrite (tellurium-containing)	14[d]	49.9	–	–	–			0.03		52.71	100.64	$Fe_{1.09}(S_{2.00}Te_{0.001})_{2.00}$
pyrite	22[d]	46.65	0.06	–	–					53.45	100.21	$(Fe_{1.00}Cu_{0.001})_{1.00}S_{2.00}$
pyrite (gold- and silver-containing)	31[d]	53.4	–	0.02	0.006	0.012			0.02	46.5	99.96	$(Fe_{1.32}Co_{0.001}Au_{0.001}Ag_{0.001})_{1.32}(S_{2.00}As_{0.004})_{2.00}$
Chalcopyrite	22[d]	30.42	34.74	–	–		0.05			34.65	99.86	$(Cu_{1.01}Fe_{1.01}Zn_{0.001})_{2.01}S_{2.00}$
Chalcopyrite	31d	30.1	34.4	0.03	0.0009	0.008				34.1	98.65	$(Cu_{1.02}Fe_{1.01}Ag_{0.001}Au_{0.001})_{2.00}(S_{2.00}As_{0.01})_{2.00}$
Sphalerite	22[d]	1.06	0.03	–	–		65.21			33.42	99.71	$(Zn_{0.96}Fe_{0.02}Cu_{0.01})_{0.99}S_{1.00}$
Sphalerite	22[d]	0.02	0.03	–	–		65.1			33.42	98.67	$(Zn_{0.96}Cu_{0.001}Fe_{0.001})_{0.97}S_{1.00}$

Development of gold took place during the sulfide stage, which manifested in the production of quartz-pyrite paragenesis (disperse gold), replaced by chalcopyrite-galena (with hypogenic notable gold) polymetallic stage, then quartz-chalcocite and has been completed by poorly manifested late quartz, calcite and barite (Imamverdiyev et al., 2013). Criteria for determining the generations are interruptions in crystallization of minerals, related to the internal ore tectonic movements and changes in acidity of the solutions and development of the main amounts of sulfides and quartz (Naumov et al., 2016; Nenakhova, 2016).

The general tendency of the evolution of physical-chemical conditions in the process of multi-stage hydrothermal mineral formation in the Dagkesaman deposits is the continuous decrease in the temperatures and pressures with inversions, accompanied by changes in the content of the main components that had separated from the ore-generating center of the fluids. Thermodynamic parameters and complex aggregate condition of mineral-forming fluids during the development of polymetallic mineralization may be explained by the likely temporal closeness of shift of hydrotherms and endogenous ore development (Naumov, 2016; Filipov et al., 2013; Malakhov, 1979).

The main ore-providing canal is the Eastern fault. This was also confirmed by the results of decrepitation of the vein quartz (Karayeva, 1976), indicating that high temperatures of occurrence of faults (300°C) fixate in the northeast flank, near the contact with rhyodacites, whereas the temperatures of hydrotherms decrease along the zone and in the southwest direction. At the same time, there was determined that the "tempo of cooling of quartz-forming fluids in the vein is ~1° per 10 m". These data, obtained according to the results of fracturing of vein quartz, explicitly indicate the orientation of the movement of ore-bearing fluids and the position of ore-providing canal (Malakhov, 1979).

In general, the results of micro-thermometric studies indicate (Karayeva, 1976; Malakhov, 1979) that the initial temperature of hydrothermal fluids that have deposited the mineral associations of the first (quartz-pyrite-sericite) stages varied within 300–240°C, and the decrepitation occurred in the temperature of 280°C. Homogenization of the primary gas-liquid inclusions in quartz took place in 240–260°C interval. Quartz-galena-sphalerite-gold ore stage had begun with deposition of a large amount of quartz in the temperature of 260–220°C, and then galena deposited, forming in the temperature of 220°C, and finally has been completed by crystallization of chalcopyrite and sphalerite in 160°C. Gold that is found with all the mentioned minerals of this stage was formed in the temperature interval of 220–160°C (Baba-zade et al., 2015).

The ores of the Dagkesaman deposits have been formed in the conditions of temperature falling from 300°C to 160°C out of low-salted hydrothermal fluids that contained chlorides Na, K and Mg, with insignificant inclusion of CO_2 HS^-, CH_4, against the background of their dilution and mixing with meteor water (Novruzov et al.,). The same conditions are the most favorable for deposition of minerals and sedimentation of Au and Ag (Borisenko et al., 2017; Volkov et al., 2018).

Significantly sulfide veins with sulfides amounting to about 50–70 % are the commonest and therefore the Dagkesaman deposits may be classified as the formation of gold-quartz-polysulfide (Baba-zade et al., 2015) or significantly sulfide ores (Petrovskaya et at., 1976). Presence of a large amount of gold in the ore zones of oxidation and partly in the pseudomorphoses of goethite and lepidocrocite in pyrite, which is the result of the decomposition of sulfuric pyrite that contains thin-disperse gold, may be an indirect evidence of presence of thin-disperse gold in pyrite-II of quartz-polymetallic stage of the development, enlarged in the process of redeposition.

Conclusions.

The most important conclusions of the study of the conditions of localization and patterns of arrangement of gold-polymetallic mineralization, mineral composition

and paragenesis of altered and mineralized zones in the Dagkesaman deposits and issues of their epithermal type are as follows:

– gold-polymetallic mineralization is mostly of vein and veinlet-impregnation type;

– mineralization is distributed quite unevenly within the ore bodies, forming relatively small sulfide-enriched regions that quickly become displaced along the dip and strike;

– mineralization is spatially related to albitophyres of subvolcanic facies. Based on monitoring made over the mineralogical studies, polymetallic ores include various types of mineralization (vein, veinlets, impregnations), usually after identifying the period of the stage of impregnated pyrite;

– near-ore processes of the containing rocks are manifested in hydrothermal-metasomatic changes (silicification, sericitization, chloritization, kaolization) up to transformation into the secondary quarcites;

– the main ore-forming minerals of the deposits are pyrite, galena, sphalenite, chalcopyrite, represented by several generations. The ores correspond to the products of quartz-pyrite-sericite, sphaleryte-chalcopyrite-pyrite and gold-chalcopyrite-galena stages of mineralization, divided by tectonic movements;

– impegnations, striped, veinlet, spotty, massive and brecia textures; brecia texture occuring mostly at the intermediate and deeper levels are distributed in the ores;

– the ores of the Dagkesaman deposits have been formed out of poorly-soluble hydrothermal fluids that contain chlorides Na, K and Mg in the conditions of 300^0C to 160^0C decrease in the temperature.

Taking into account the aforesaid, we may presume that the Dagkesaman gold-poly metal deposits may be identified to epithermal system of high sulphidation.

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The Mangrove Forests of the Cameroon Coast and its Socio-Economic Significance

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Abstract. The study analyses anthropogenic influence on the mangrove forests of the Cameroon coast and focuses on the development and improvement of the constructive-geographical foundations of rational nature management for the conservation and possible renewal of its natural resources base. The exploitation of mangrove forest landscapes has yielded significant benefits to the local population living within the mangrove forest limits, but the beneficiaries have not made commensurate investments in their sustainability and rational use. Therefore, this habitat must be carefully conserved or protected from wanton anthropogenic activities for the development purpose. The study made use primary and secondary data in establishing the facts analysed in this work. The secondary data comprised of materials of prominent authors who have contributed much to the findings related to coastal mangroves. Primary data collection was field visits carried out by the author in 2016. Questionnaires and semi-structural questions were used to collect information from mangrove exploiters. The findings confirm that the coastal mangrove forests in Cameroon have multiple functions beneficial to the communities adjacent to the coast, but, unfortunately, the beneficiaries have not made commensurate efforts to their sustainability and rationale. The Mangrove forests covered a surface area of 200 000 km^2, but Cameroon lost 30 % of its mangrove forest cover in 1980–2006. If projected under *ceteris paribus*, Cameroon lost approximately 45 % of its mangrove forest cover in1980–2020. Haven understood that man has raped huge surfaces of mangrove forest for his selfish economic gains, the study proposed an urgent need for environmentally sustainable adaptive strategies like those earmarked in the Ramsay agreement and the ICZM (Integrated Coastal Zone Management) for the rational management of coastal mangroves in Cameroon.

Ключові слова: Mangrove forest, Cameroon Coast, socio-economic, rational management

Мангрові ліси на узбережжі Камеруну та їх соціально-економічне значення

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Анотація. Дослідження присвячене аналізу проблеми антропогенного впливу на мангрові ліси узбережжя Камеруну, а також розробці та вдосконаленню конструктивно-географічних основ раціонального природокористування для збереження та можливого відновлення його природно-ресурсної бази. Надмірна експлуатація цих мангрових лісових ландшафтів принесла більші переваги місцевому населенню, яке мешкає в межах мангрових лісів, але бенефіціари не зробили відповідних інвестицій з точки зору їх стійкості та раціонального використання. Отже, це середовище існування повинно бути ретельно збережене або захищене від безглуздої антропогенної діяльності в ім'я розвитку. Під час дослідження було використано первинні та вторинні матеріали для встановлення фактів проаналізованих в даній роботі. Вторинні дані представлені у вигляді праць відомих дослідників, які внесли значний вклад у вивчення прибережних мангрових заростей. Проведені автором в 2016 році польові дослідження стали основою для написання статті. Для збору інформації було проведено опитування та анкетування експлуататорів мангрових заростей. Дослідження показали, що прибережні мангрові ліси Камеруну виконують безліч функцій, які приносять користь громадам, прилеглим до узбережжя, проте від людей не спостерігається пропорційних зусиль для забезпечення стійкості та раціонального їх використання. Раніше мангрові ліси займали площу 200 000 км^2, але з 1980–2006 рр. Камерун втратив майже 30 % від загальної площі. Згідно спостережень з 1980–2020 рр. Камерун втратив приблизно 45 % мангрового лісового покриву. У дослідженні Хейвена (основу якого покладено в дану статтю) йдеться про те, що людство знищило величезні площі мангрових лісів заради своєї егоїстичної економічної вигоди; в дослідженні пропонується терміново розробити екологічно стійкі адаптивні стратегії, подібні до тих, які передбачені в Рамсейській згоді та КУПЗ (Комплексне управління прибережною зоною) для раціонального управління прибережними мангровими заростями в Камеруні.

Ключові слова: мангрові ліси, узбережжя Камеруну, соціально-економічне значення, раціональне природокористування.

Introduction.

Cameroon is one of the Central African countries located at the heart of the Gulf of Guinea, within the Bay of Biafra, covering a surface area of 475, 412km^2 (*Sayer et al, 1992*) with a population of approximately 25 million inhabitants. This coastal zone is characterized

by the equatorial climate and consists of a vast coastal environment which is an extension of the Atlantic Ocean with a coastline of about 402km. This coastline extends from 2° 20' N at the Equatorial Guinea borders to 4° 40' N at the Nigeria borders and between 8°151E and 9° 30E (Fig. 1). With a continental shelf of about 10.600km^2 (Jean Folacky, 2004) and an Exclusive Economic zone (EEZ) of about 15,400km (Jean Folacky, 2004) it forms a convivial environment that harbors a wide range of aquatic ecosystems which are typical for the coastal plain of the Atlantic. This includes ocean, coastal forests, deltas, sand dunes, mangroves, coastal rivers, estuaries, lagoons, bays, lakes, rocky and sandy beaches, mudflats. It is drained by major rivers (Ndian, Meme, Mungo, Wouri, Dibamba, Sanaga, Nyong and Ntem), with a total drainage river basin of about 2.7 x 105 km^2 with the Sanaga contributing the highest sediment load (2.8 x 102 km^3 / year).

Cameroon is richly endowed with mangrove forests which covers a surface area of about 200 000 ha extending from the Rio Del Rey Estuary to the Ntem Estuary Mangroves. These mangrove forests have a huge value for the coastal adjacent communities that derive their livelihoods from them. However, today, the rate at which this unique forest ecosystem is degraded leaves much to be desired.

These mangroves can be grouped into three distinctive fragments, Fig. 1. We have the Rel Dey Rey estuary mangroves which occupies the largest area (54 %). It is situated mainly in the south west region of Cameroon, precisely from Bakassi to Limbe.

We equally have the Cameroon estuary mangroves which cover (45 % of the coastline. It is situated in part of the south west region (Mount Cameroon, Tiko) and the entire Littoral region, through the Wouri estuary to the Sanaga estuary.

Finally, we have the Ntem estuary mangroves which occupy (1 %). This extends through the south region to the borders with Equatorial Guinea. The mangrove forest ecosystem provides important ecosystem goods and services to the mangrove forest adjacent communities.

These communities have hugely benefited from these ecosystem goods and services, but have made little or no efforts towards their sustainability. Cameroon is witnessing a very high rate of anthropogenic pressure on the mangrove forest ecosystem. This pressure has resulted in the de functioning of this unique ecosystem.

Despite the laudable efforts both nationally and internationally through a variety of projects and programmes initiated in Cameroon through organisations, such as FAO, WWF, EU, the Guinea Current Large Marine Ecosystem (GCLME) project and the United Nations Environmental Programme (UNEP) for the conservation and preservation of mangroves, it remains very glaring that the mangrove forest ecosystem has still not received the adequate attention it deserves from policy makers.

The mangrove forests disappear drastically because of over-exploitation of their resources, fuel wood, conversion of mangrove surroundings for other land uses, such as agriculture, coastal landfill, pond aquaculture and urbanization with its concomitant effects of population growth and pollution.

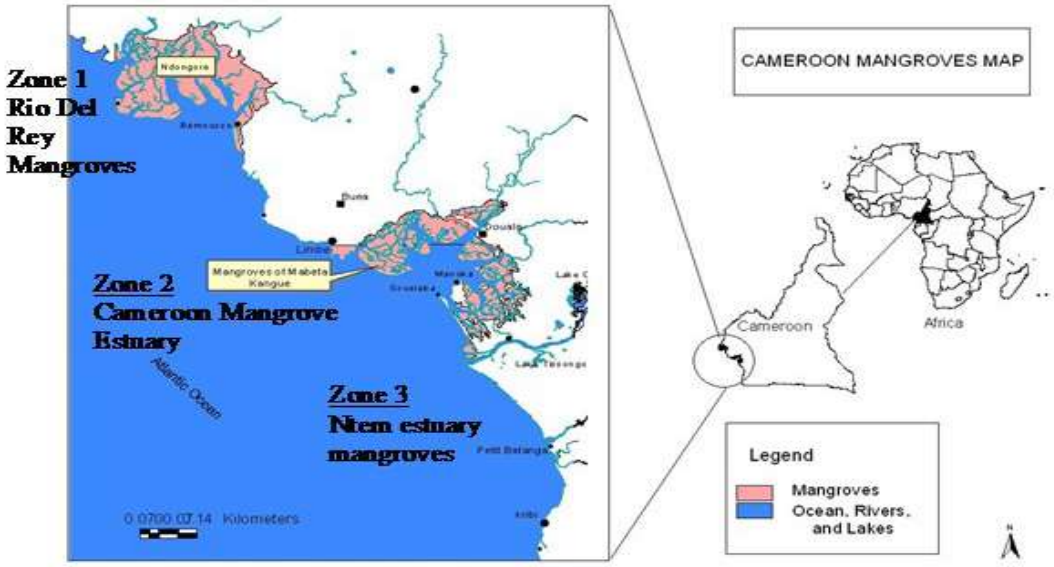

Fig. 1. Map of Coastal Mangrove in Cameroon

Over the past decades, much concern on the degrading nature of the mangrove ecosystem has been highlighted. This action has drawn the attention of policy makers all over the world to give a special attention on this peculiar ecosystem which is at the verge of extinction.

Review of previous researches.

Some of the works have been reviewed in this study. In Africa, the Cameroon mangrove forest is the 6th largest and first in Central Africa in terms of surface occupation (Ajonina, 2008). Therefore, Cameroon is ranked as one of the most giant mangroves in the World (Ajonina, 2008) Fig. 2. According to (Ellison and Zouh, 2012), the continuing degradation and depletion of this unique ecosystem has the possibility of reducing not only the terrestrial, aquatic production and wildlife habitats, but more importantly, the environmental stability of mangrove coastal forests that acts as a buffer zone to the inland agricultural crops and villages will become severely impaired. In their study related to the shrinking of Africa's mangroves, (Ajonina, 2008) underscored that these mangroves have been increasingly affected by deforestation. In the West Africa, mangrove areas have diminished from 20,500 km^2 in 1980 to 15 800 km^2 in 2006. In Central Africa they have reduced from 6,500 in 1980 to 4300 km^2 in 2010. While it is estimated that Eastern Africa's mangroves have decreased from 2 555 km^2 in 1980 to 7 211 km^2 in 2010, (The Encyclopedia of Earth, 2007). Conclusively, according to (FAO, 2007), Africa has lost up to 500 000 hectares of mangroves over the past 25 years. Other related findings on mangrove forest include the works of (FAO, 2007, Feka, Manzano and F. Dahdouh-Guebas, 2011, Simon and Rafaelli, 2012 and The Encyclopedia of Earth, 2007). Mangrove forests cover about 152 361 000 ha of the tropical and sub-tropical coastlines of the world. Their degradation and possible reduction can be quantified to the loss of numerical functions like ecological, conservation, and the sustenance of the mangrove forest adjacent communities who solely depend on them for their livelihood (The Encyclopedia of Earth, 2007). Nonetheless, the wanton exploitation of this unique ecosystem in the West African coast has favoured a decline of about 25 % of mangrove forests over the past 25 years (Din and Baltzer, 2008, FAO, 2007). According to (Ajonina and Usongo, 2001), Cameroon has equally lost about 53.216 ha of mangrove forests over the last 13 years (Ngo-Massou et al., 2016). This situation is very unhealthy, as their sustainability is a stake. Due to the lack of political regulation in the management of coastal ecosystems, anthropogenic activities play a major role in the reduction of mangrove biodiversity and the provision of ecosystem services (Ndema-Nsombo et al., 2015, UNEP, 2007).

Results and their analysis.

The coastal mangrove forest of Cameroon provides a rich biodiversity and peculiar ecological niche for the service of the forest-adjacent communities. The communities exploit the forest for food, household fuel wood, and medical plants. The forests are vulnerable to degradation and deforestation activities, such as logging and slash-and-burn agriculture. The location of mangroves at the heart of the economic capital, which is the industrial hub of the country, is another cause for concern. Heavy industries which require more water for heating and cooling of their machines are all situated along the mangrove coast. The discharge of their waste products cannot be underestimated, as these wastes are not treated and no less toxic for the survival of aquatic life, including mangroves. Fig. 3 is a summary of the industries located along the Cameroon coastal mangrove area.

This section examines and analyses the main causes of mangrove decrease, their dynamics, and mutations over time. The final part will be the results of this mutation if they have helped in improving the sustainability of mangroves or they are considered a threat to the mangrove forests. Some adaptive environmentally sustainable measures will be recommended for the preservation and conservation of this unique ecosystem witnessing the ultra-fast rates of degradation.

The evidence from the Fig. 2 buttresses the truth that the mangrove forests of the Cameroon coast are situated in the heart of the economic capital of Cameroon. Hence, industrial pollution is eminent as shown in the Table 1. The evidence from the Fig. 2 buttresses the truth that the mangrove forests of the Cameroon coast are situated in the heart of the economic capital of Cameroon. Hence, industrial pollution is eminent as shown in the Table 1.

Table 1. Producers of petroleum effluents in Douala-Cameroon

Company	Product	Contaminant
CIAC and PLASTICAM	Producers of plastic buckets, paints and tyres	Hydrocarbons, Tubes
SAPCAM	Paint production	Combustible fuel oils
CONFITEX	Textiles	Acid waste oils
TOTAL FINAELF	Crude oil exploitation and marketing oil products	Hydrocarbons and lead (pb)
SCDP	Oil products storage and distribution	Oil dumps (contains lead, Arsenic copper etc.)
SHELL TEXAACO	Aviation, petrol, diesel fuel and wax	Hydrocarbons, lead, cadmium, copper, zinc and other trace metals
CEP/CHEMICALS	Paints, detergents, vanish	Acid mercury, copper, lead, phosphates, trace metals etc.

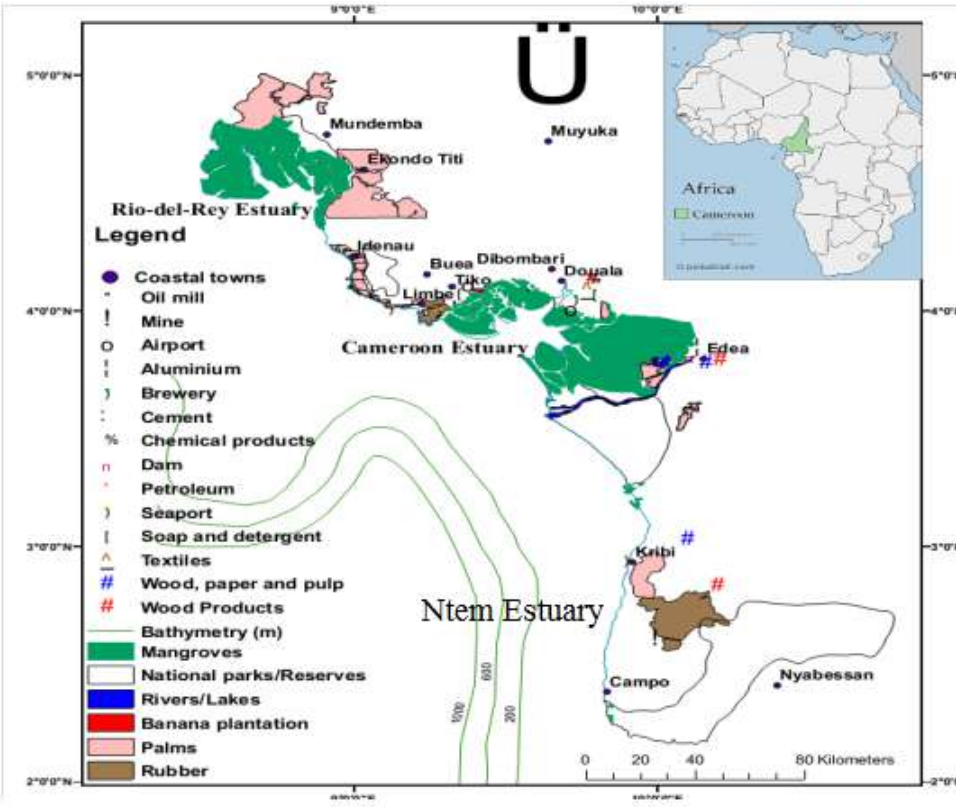

Fig. 2. Major Economic Activities along the Cameroonian Coast

Added to the above, the main Agro-industrial establishments, which have equally contributed to the bastardization of this zone, include HEVECAM. SPFS. SOCAPALM. SAFACAM. CDC and PAMOL. The CDC alone employs over 15 000 persons for a cultivated area of more than 90.000 ha, making it the second largest employer after the state. It is recommended that a detail analysis of the impact of the drivers to mangrove existence be carried out with field measurements and the use of satellite images.

The dynamics of Cameroon coastal mangroves: Indeed, Cameroon since its independence has made conservation a major priority which is recognized as a step towards the aspiration of the sustainable management of the forest and its resources. Cameroon has revised the forest policy in order to meet this aspiration. A framework Law No 96/12 dated 05/08/96 had Article 94 put in place to preserve and conserve its ecosystems. Although, despite these laudable efforts, it is obvious that policy makers have not given the mangrove forests of the Cameroon coast the adequate attention they deserve. This unique ecosystem has been the most disturbed in modern times and in a continuous decline within the last decades, Table 2. These forests are located at the land-sea interface; thus, they constitute a highly productive ecosystem with rates of primary production equal to those of the tropical humid evergreen forests (Alonji, 2002). They accumulate carbon in tree biomass and most of this carbon is lost by decomposition and export to the adjacent ecosystem (Alonji, 2002).

The main economic activity in this zone is traditional fishing. This activity equally has a negative impact on the mangrove ecosystem. The increasing demand of smoked and roasted fish has a direct impact to the supply of fuel wood. Mangrove wood is preferable to any other wood because it burns very slowly and its charcoal is considered the best for this purpose.

Table 2. Available data of Cameroon Mangrove Estimates (FAO, 2007)

Year	1980	1990	1997	2000	2005	2006
Area km^2	2720	2563	2494	2515	2500	1957

Fig. 3. Wood Exploitation in the Tiko Mangrove Forest

An urgent need to detect, preserve and restore the degraded mangrove forest at the Cameroon coast will be a welcome initiative in order to preserve the natural resources for posterity. The «matanda warriors» go deep into the creeks along the Tiko shores with the use of canoes, cut the trees and haul them to the beaches for splitting into firewood for sale. Red mangrove (*Rhizophora sp.)* is by far the most solicited species used for fuel wood, fish smoking and roasting, and timber.

Other factors that impact the rate and quality of a mangrove's self-restoration include large portions of land that consist of industrial estates of oil palm, rubber, tea and bananas. With the population increasing large acres of arable land are put under cultivation to feed the growing population.

Another issue of concern in this maritime zone is the progressive degradation of the marine and coastal ecosystems caused by the over-exploitation of its fishery resources, coastal erosion and industrial pollution. This zone like any other coastal environment has witnessed rapid urbanization, uncontrolled industrialization, port and maritime activities. The exploitation of petrol and unlawful discharge of toxic wastes have exposed this zone to land, air and water pollution. A glaring example is the Rey Del Rey and Ntem estuaries which are highly abused and threatened by oil and gas exploration. Over 5 million inhabitants living adjacent to the coast is evidence that livelihood is solely dependent on the natural resources within their disposal. This population has altered the landscape through unsustainable and uncontrolled implantation of agro-industrial plantations and a handful of infrastructural development facilities.

Measures to protect the mangrove ecosystem in Cameroon: Despite the legal provisions binding the exploitation of coastal mangroves in Cameroon, much is still expected if Cameroon wants to protect, conserve and rationally manage its mangroves resources. Coastal mangroves in the country are legally protected since 1996 (Frame law No 96/012 relative to the management of environment in Cameroon), but the peri-urban environs of the Douala mangroves alone have experienced a loss of 53.16 % in the last 3 decades and the degradation continuous progressively. Wildlife habitats have been affected to the extent that even their rehabilitation cannot provide a reasonable shelter that can be used to combat climate change.

Since the coastal communities depend primarily on the exploitation of these resources for their livelihood it is only through a participatory management that the sustainability of this zone can be achieved. The communities should have a say in the management of the resources they depend on.

The implementation of an International protocol for the protection of nature should be applied in this zone. This includes agreements, like the Integrated Coastal Zone Management (ICZM) which stands for the sustainable development in coastal areas. The Ramsar Convention on wetlands of international importance, of which Cameroon is a signatory, remains an important instrument for the management of this unique ecosystem. This convention has put in place a mechanism that works for the conservation and wise use of all wetlands through local, national and international assistance.

Taking into cognisance the importance of coastal zones, the government has to facilitate the training of young scientists on the management of coastal and marine zones. More skilful professionals with excellent knowledge of suitable programmes for nature management are required. Modern technology (GIS) and related software, like Mapinfo and suffer 9 can be used to analyse and monitor changes occurring in the mangrove zone.

Conclusion.

A combination of physical and human activities is responsible for the intensive degradation of the mangrove's ecosystem. But the anthropogenic factor is at the forefront.

An urgent need to detect, protects, and restore degraded mangrove forests is a major step towards an environmentally sustainable management of natural resources. These zones are experiencing an increasing magnitude of global environmental change processes exhibited by catastrophic events, such as tropical cyclones, tsunami and tidal bores, flooding, saline water incursion, deepening shoreline erosion, wetland loss and the threat of sea level rise.

The fact that this zone is overcrowded with diverse social and economic activities is evidence that the carrying capacity of the coastal environment is undergoing an accelerated decline in receding shorelines, loss of biodiversity and increasing human pollution. Policy makers must, therefore, pay more attention and implement adaptive environmental strategies to enhance their sustainability.

To safeguard aquatic resources from water pollution, industrial wastes should be treated before disposal.

Cameroon has lost 45 % of its mangrove forest. If the rate of deforestation and degradation continues unabated, mangrove forest at the Cameroon coast will be history in the next 60–70 years. It is, therefore, time for the government to create protected areas and monitoring groups to give routine reports. The amelioration of swampy flood plains and the harmonious management of the relationship between nature and the society are of immense importance to the protection of this fragile ecosystem. A constructive geographical direction that manages natural resources not only enables resource availability today, but it also ensures sustainability for future generations.

A program to monitor, control and sustain fishing activities in the mangrove areas of Cameroon was developed in 2009, along with a program to monitor socio-economic aspects to ensure the sustainable management of these areas. However, there is still a lot to be done, because policies can be good on paper but poor in execution. Government enforcement of this policy remains vital in order to conserve and rationally manage mangroves in the coast of mangrove.

Rational use of natural resources in the coastal zone, with emphasis on the mangrove forest must comprehensively take into consideration the physical-geographical and socio-economic processes, as well as the national and international laws binding their exploitation. They must equally execute developments that determine the current state and dynamics of changes in natural systems during their operation. The activities of integrated managements of coastal mangroves in different countries of the world were analyzed basing on a detailed and well-structured study of domestic and foreign publications related to this topic. Some environmentally sustainable adaptive strategies that can be the scientific basis for the relevant legislative frameworks for the optimization of nature management and spatial planning of coastal zones have been proposed with the aim to safeguard the mangrove ecosystem from extinction within Cameroon.

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Spatial Evaluation of Groundwater Quality Using GIS and WQI in Gadilam River Basin, Tamil Nadu, India

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Abstract. The aims of the current research are to assess the drinking water quality of the groundwater in the Gadilam River Basin, which is located in the northern part of Tamil Nadu, by identifying the groundwater quality index and examine its suitability for drinking. The current work determines the levels of groundwater quality parameters based on 120 groundwater samples; 50 samples from Archaean formation, 34 samples from Quaternary formation, 35 samples from Tertiary formation and the remaining sample from Cretaceous formation. Additionally, this research compares the determined levels with the various standards for drinking. Furthermore, the variability of parameters of the groundwater quality is explored in this paper by using the spatial interpolation method. The conclusion of this research reveals that the groundwater quality parameters such as Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Nitrate (NO_3^{2-}), Fluoride (F^-), Sulphate (SO_4^{2-}), Bi-carbonate (HCO_3^-) and Percentage of Hydrogen (pH) values are observed to be within the limiting value for WHO 2017 in all the formations during the seasons in which they were taken. The water quality index (WQI) values of the Archaean, Quaternary and Tertiary formations are found to be less than 100 meq/L in all stations in both seasons. In order of WQI, these stations come under the category of "Excellent" and "Good". The Piper trilinear classification of groundwater samples fall in the field of mixed Ca-Mg-Cl, and No dominance, some of the samples represent Na-K, Cl types of water.

Keywords: Archaean, Quaternary, Tertiary, Cretaceous, groundwater, water quality.

Просторова оцінка якості підземних вод з використанням геоінформаційних систем (ГІС) та індексу якості води (WQI) у басейні річки Гаділам, Тамілнад, Індія

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Анотація. Метою данного дослідження є оцінка якості підземних вод у басейні річки Гаділам, розташованої в північній частині Тамілнаду як джерела питної води, шляхом визначення індексу якості підземних вод та вивчення їх придатності для питного споживання. Представлена робота визначає рівні параметрів якості підземних вод на підставі дослідження 120 проб підземних вод: 50 зразків з архейської формації, 34 зразка з четвертинної формації, 35 зразків з третинної формації та однієї проби з крейдової формації. Крім того, це дослідження порівнює визначені рівні з різними стандартами до питної води. Крім того, мінливість параметрів якості підземних вод досліджується в цій роботі за допомогою методу просторової інтерполяції. На завершення цього дослідження виявляється, що такі параметри якості підземних вод, як кальцій (Ca^{2+}), магній (Mg^{2+}), нітрат (NO_3^{2-}), фтор (F^-), сульфат (SO_4^{2-}), бікарбонат (HCO^{3-}) та водневий показник (pH) спостерігаються в межах граничного значення для ВООЗ 2017 у всіх формаціях протягом цього сезону. Значення індексу якості води архейських, четвертинних та третинних утворень (WQI) є меншими за 100 мекв/л на всіх станціях в обидва сезони. Відповідно оцінки WQI, ці пункти спостереження належать до категорії «Відмінно» та «Добре». За трилінійною класифікацією Пайпера проби підземних вод потрапляють в область змішаних Ca-Mg-Cl із відсутнім домінуванням, деякі зразки у типах Na-K і Cl типи води.

Ключові слова: архей, четвертинний, третинний, крейдовий період, підземні води, якість води.

Introduction.

Water plays a vital role in human life. The consequences of urbanization and industrialization lead to deterioration of the quality of the water (Sanjay et al 2007). During the last few decades, it has been observed that groundwater is becoming polluted drastically because of rapid industrialization, improper dumping of solid wastes and toxic waste management (Yousefi et al., 2018). Consequently, the number of cases of waterborne diseases causes health hazards, while the use of such water for agricultural purposes lead to adverse effects on crop production and fertility

of agricultural soils (Pirsaheb et al., 2014; Asghari et al., 2018; Muthusaravanan et al., 2018).

All over the world, groundwater is used for many purposes including irrigation, domestic, moreover industrial uses. Pollution has increased in the last few decades due to the continuous-increment in population. This increase is significant to the demand for fresh water as a result of the rapid development of the population and the expanded rate of progress in industrialization. Decrease in water quality happens to be a worldwide issue of focus since human populations are increasing, agricultural and industrial activities are expanding, additionally climate change poses the threat of major changes to the hydrological-cycle (Federation and APHA, 2005).

The groundwater quality depends mainly on the geological formations and anthropogenic activities. There are many studies regarding the excessive extraction of groundwater and resulting sea water intrusion contaminating coastal aquifers (Bagade, 1995; Thigale et al., 1998a; Duraiswami et al., 2000). Increased usage of groundwater has depleted the sources of groundwater. The excess concentration of certain ions has made the water unfit for drinking and irrigation uses. The discharges from industries and land resources have led to serious problems in the water quality. Public health and agriculture have been gravely impaired due to consumption of contaminated water and depleted groundwater source.

According to the WHO organization (WHO, 2017), nearly 80 % of all human diseases are caused by water. Hence the quality of water must be expressed in the most common form to analyze the water characteristics. Whenever groundwater is contaminated or degraded, its quality fails to recover unless contaminants are prevented from penetrating through the source. The guidelines and standards for drinking water quality are planned to ensure that perfectly clean and protected water is distributed for human consumption, with the intention of protecting people's health. For that reason, it is necessary to continuously monitor the groundwater quality and to protect it.

The general target of any assessment for groundwater quality is often to get an all-inclusive evaluation of variations of the quality of groundwater and evaluate the changes that occur in the groundwater quality over time, either in a natural way or under human pressure (Tiwari and Nayak, 2002).

Several authors have studied the hydrogeochemistry of groundwater and vulnerability of the aquifers to pollution in hard rock aquifer of peninsular India. Rina et al., (2011), Singh et al., (2012a and 2012b) studied hydrogeochemical evolution of groundwater. Prasanna et al., (2011), Sonkamble et al., (2012), Brindha et al., (2013), Brindha and Kavitha (2014), Kumar et al., (2014), Rajesh et al., (2015) investigated aquifers in various rock domains like granite, gneiss, schist and basalt to enumerate the geochemical evolution of groundwater and its suitability for various use.

The Water Quality Index (WQI) is the most considerable tool that is effective in conveying information about water quality to concerned citizens along with policy makers. It really is a strategy which is efficient in determining the water characteristics (Singh 1992, Naik et al. 2001, Mishra et al. 2001). The Water Quality Index therefore, becomes a crucial parameter used in the management and assessment of groundwater. It can help in classifying groundwater: whether or not it is fit for irrigation. WQI is computed from the standpoint of groundwater suitability for irrigation consumption. WQI is distinctive as a score that reflects the composite-effect of a variety of water quality parameters. The calculation of the WQI in groundwater study started with Horton (1965) and Landwehr (1974). Wu et al. (2011) reported that the selection of water quality parameters is a necessity in evaluating the primary anthropogenic activity in the monitoring location. The primary anthropogenic activity may be domestic, agriculture, mining, etc. It is possible to determine the groundwater quality index (GWQI) by analyzing several important parameters and assign a proper weight for each one.

Study Area.

The Gadilam River originates from Kallakurichi district and flows through Viluppuram district to meet the Bay of Bengal in Cuddalore district. This river total flow length is 102 km and catchment area is 2091.20 sq.km. It is reported that the river gets a supply of occasional floodwater from the Ponnaiyar River through the Malattat River. The Gadilam River basin is extended from 11°26'31.797" N to 11°56'29.633" N latitudes and 78°59'10.675" E to 79°47'15.793" E longitudes (Fig. 1).

It is represented on Survey of India topographical maps 58I/13, 58M/1, 58M/2, 58M/5, 58M/6, 58M/7, 58M/9, 58M/10, 58M/11 and 58M/15 on a scale of 1:50,000. The study area is bounded by Villupuram in the north, Cuddalore town in the east, Thirukoilur in west, and Vadalur in the south. There are a number (1024) of tanks in the study area, of which, 62 major (above 0.5 sq.km) tanks are noted. The temperature reaches its maximum during April and May 38° to 39 °C, minimum in January and February 24° to 25 °C. The wind velocity is highest during summer and sometimes during the monsoon seasons.

The present study area catchment area of the basin is located in Kallakurichi district, the mature stage of the river basin flow in Viluppuram district and the lower river basin is in Cuddalore district. Agriculture is the major occupation in the entire Gadilam River

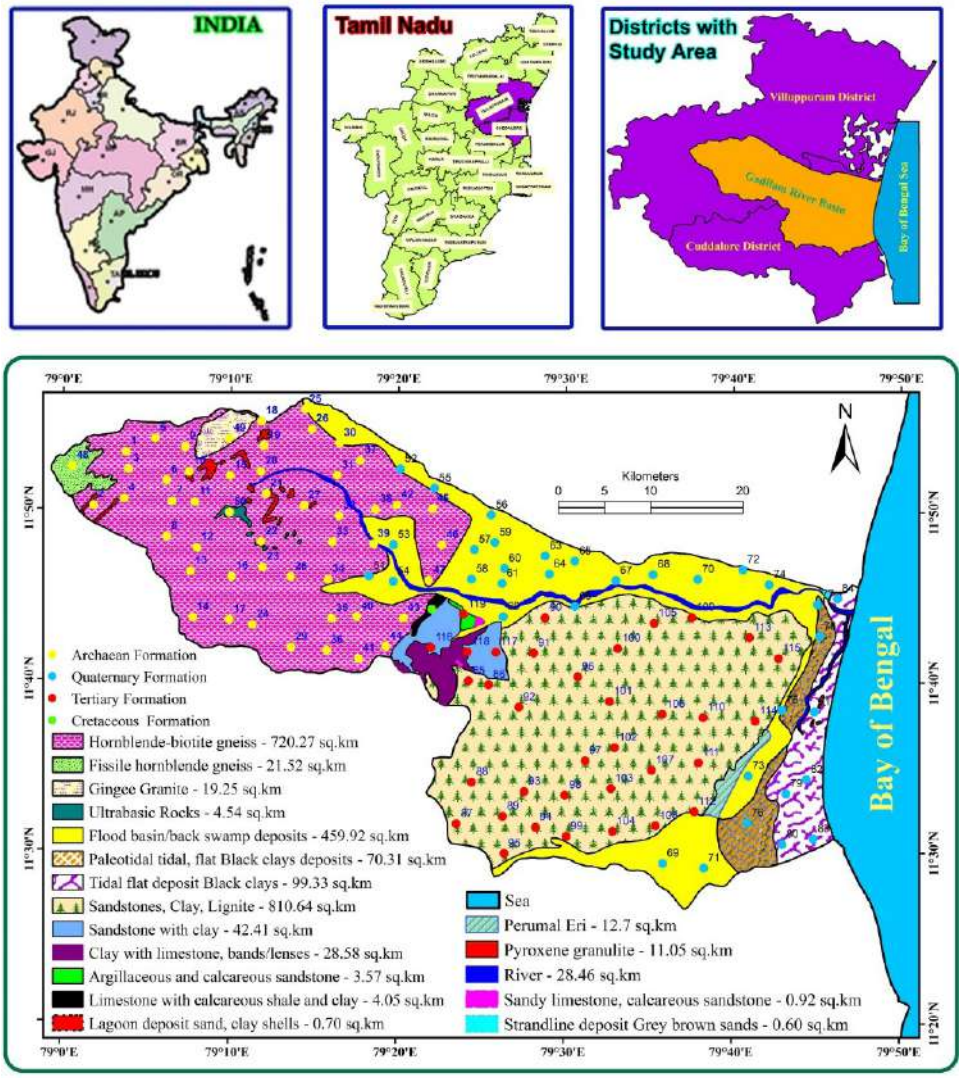

Fig. 1. Key Map of Study Area

Basin. Most of the area's irrigational, domestic and drinking needs are supplied by groundwater resources, and demand for this has increased in recent times. The drilling of new bore wells and extensive exploitation of groundwater have affected the groundwater quality of the study area. Besides, large scale farming and paddy cultivation leads to use powerful pumps for withdrawing groundwater, and this could deplete the sources at a much faster rate. Hence, an understanding of groundwater quality characteristics for drinking and irrigational needs of the region is necessary in order to ensure continuous agricultural activity. Besides, the study of groundwater quality characteristics has not been attempted in the recent times in the study area (Shankar et al., 2011; Layeek Ahamed et al., 2014).

Materials and Methods.

The Gadilam River Basin boundary is demarcated based on the drainage system using Survey of India topographical maps 58I/13, 58M/1, 58M/2, 58M/5, 58M/6, 58M/7, 58M/9, 58M/10, 58M/11 and 58M/15 on 1:50,000 scale and drainage updating in current satellite data (Landsat-8 TM data, March-2018). The geology map is traced from the district resources map. The Gadilam River upper basin shows an Archaean formation and the lower basin shows Tertiary uplands in the south and recent alluvium (Quaternary) in the north (Fig. 1). A detailed methodology flowchart is given in Fig. 2.

Overall, 120 groundwater samples were collected from the Gadilam River Basin excluding the reserved forest area. Fig. 1 shows the distribution of the 50

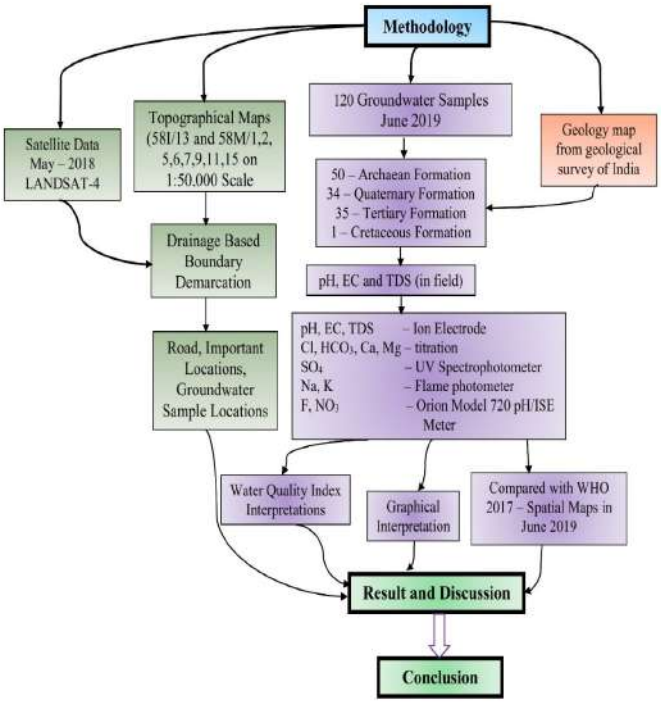

Fig. 2. Detailed methodology flowchart

samples which were collected from the Archaean formation (hornblende-biotite gneiss, fissile hornblende gneiss, Gingee granite and ultrabasic Rocks). 34 samples from the Quaternary formation (flood basin/back swamp deposits, Paleotidal tidal, flat black clay deposits, tidal flat deposit black clays) and another 35 samples from Tertiary formation (sandstones, clay, lignite, sandstone with clay, argillaceous). The single remaining sample is from the Cretaceous formation. Groundwater samples were collected using 1liter plastic containers. To ensure the collection of representative groundwater samples from the borehole and dug-wells groundwater samples were collected during June 2019. The analysis of elements and parameters in the laboratory followed the standard methods. Each water sample from the collected samples was assessed for fourteen parameters such as TDS, TH, pH, EC, chloride, sulphate, sodium, magnesium, calcium, nitrate, potassium, fluoride and bi-carbonate using standard-procedures of water test advised by the Federation and APHA (2005).

At each location the coordinates were taken using a GPS, GARMIN eTrex 10 model. These locations were entered into GIS software and we developed the attribute in points with spatial data. The spatial distribution maps of pH, EC, TDS and major cations, anions and selected heavy metal were produced using Arc GIS 10.2 using the inverse distance weighted method IDW (Suresh et al., 2010; Vetrimurugan et al., 2017).

Each and every parameter was correlated with WHO 2017 and BIS 2012 standards. Any measurement above the value of the same standards was assigned a classified risk hazard rank. Based on this rank, spatial thematic maps were prepared. After creating the entire thematic layers using SMCE, overlay analysis was conducted using all the thematic layers and finally, to identify the risk hazard and high risk hazard zones.

Groundwater quality index (GWQI) is calculated in accordance with the following equation.

$$GWQI = \frac{\sum_{i=1}^{n} W_1 \; q_1}{\sum_{i=1}^{n} W_1} \quad (1)$$

The quality rating is calculated according to the following equation.

$$q_{n1} = \frac{(V_{actual} \; V_{ideal})}{(V_{standard} \; V_{ideal})} X \; 100 \quad (2)$$

where,

q_{ni} is the quality rating of the i^{th} parameter for the total (n) number of the water quality parameters.

V_{actual} is the measured value of water quality parameter (found from the laboratory).

V_{ideal} is the standard value of water quality parameter (found from standard tables).

The value of V_{ideal} for pH is 7 and for the other studied water quality parameters is zero.

Results and Discussion.

The Archaean, Quaternary, Tertiary formation minimum, maximum, average and standard deviation values of physio-chemical parameters during November 2018 results are shown in Table 1.

Table 1. Formation wise statistical results of groundwater Physio-chemical Parameters

Physio-Chemical Parameters	Desirable Values for WHO – 2017		Archaean – 50 Samples				Quaternary – 34 Samples				Tertiary – 35 Samples			
			November 2018											
	Most desirable limits	Maximum allowable limits	Min.	Max.	Ave.	Std. Dev.	Min.	Max.	Ave.	Std. Dev.	Min.	Max.	Ave.	Std.Dev.
Ca^{2+} (mg/L)	75	200	27.00	146.00	80.46	27.50	21.00	149.00	66.41	28.49	16.00	126.00	46.83	22.98
Mg^{2+} (mg/L)	50	150	12.00	77.00	42.36	15.47	6.00	80.00	33.88	16.05	7.00	60.00	22.34	11.68
Na^{+} (mg/L)	-	200	40.00	250.00	143.44	47.10	35.00	600.00	159.00	120.24	29.00	196.00	83.26	43.00
K^{+} (mg/L)	-	12	6.00	50.00	24.12	9.78	5.00	100.00	24.50	21.79	4.00	40.00	12.26	7.54
NO_3^{2-} (mg/L)	-	45	4.00	40.00	20.96	7.64	3.00	29.00	13.65	6.38	3.00	20.00	9.74	4.66
Cl^{-} (mg/L)	200	600	48.00	448.00	168.64	91.69	24.00	816.00	178.71	183.53	24.00	224.00	77.54	42.81
F^{-} (mg/L)	-	1.5	0.00	1.20	0.58	0.39	0.00	1.20	0.45	0.37	0.00	1.20	0.34	0.29
SO_4^{2-} (mg/L)	200	400	50.00	395.00	173.12	75.52	40.00	394.00	152.26	69.74	40.00	365.00	115.26	64.04
HCO_3^{-} (mg/L)	300	500	52.00	428.00	286.04	79.97	56.00	624.00	266.88	134.18	56.00	362.00	172.63	97.73
EC (µmohs/cm)	-	1500	454.00	2600.00	1448.70	469.13	372.00	3400.00	1377.74	740.66	288.00	1887.00	809.57	403.34
pH	6.5 – 8.5	9.2	7.12	8.12	7.51	0.28	7.17	8.05	7.44	0.23	7.21	8.21	7.52	0.25
TDS (mg/L)	500	1500	318.00	1820.00	1014.14	328.36	260.00	2380.00	964.15	518.80	202.00	1321.00	566.77	282.38
TH (mg/L)	100	500	116.00	684.00	377.64	132.97	88.00	704.00	307.06	137.64	72.00	568.00	210.51	105.79
T.Alk(mg/L)	-	500	52.00	428.00	286.04	79.97	56.00	624.00	266.88	134.18	56.00	362.00	172.63	97.73

The concentration of the Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Nitrate (NO_3^{2-}), Fluoride (F^-), Sulphate (SO_4^{2-}), Bi-carbonate (HCO_3^-) and percentage of Hydrogen (pH) values are observed to be within the limiting value for WHO 2017 in all the formations during this season.

Sodium (Na^+) values were found to be not permissible in some samples from the Quaternary and Archaean formations due to the presence of concentrated colloids in the water (Akhilesh Jinwal et al., 2008). All sample values were observed to be within the limiting value for WHO 2017 in the Tertiary formation. The sodium concentration of the three formations shows that the Quaternary formation has the highest value (600 mg/L) and in the Archaean formation the maximum value (250 mg/L) was noticed.

From the spatial variation with contour lines of the Na map (Fig. 3) excess over the limit for drinking purposes was seen, twelve samples in these sample places in the Archaean formation were located in between (contact zone) hornblende-biotite gneiss and the flood basin. Therefore, it is the weaker plane which may have significant influence of rock water interaction (Rajmohan et al., 2000).

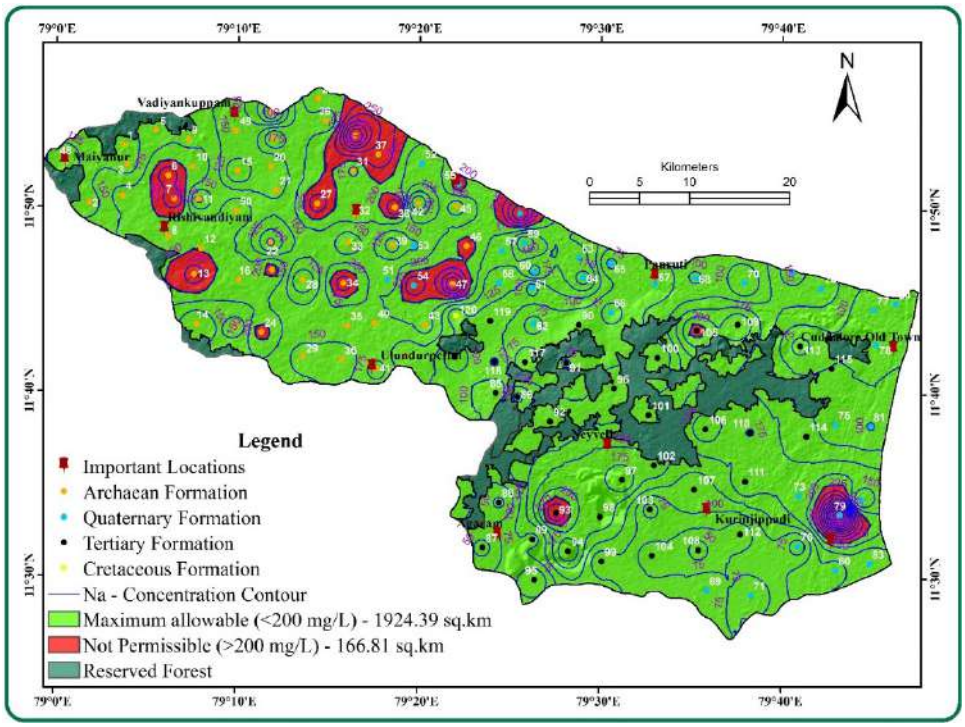

Fig. 3. Sodium spatial variation map – WHO 2017

Only four such samples were studied in the Quaternary formation. These sample places were located in between (contact zone) the flood basin deposit with hornblende-biotite gneiss and the sea shoreline. Therefore, it is the weaker plane that may have considerable influence of rock water interaction and there may be sea water intrusion to the fresh groundwater.

In the Tertiary formation only two samples of groundwater were found to be outside the permissible limit. These sample places were located in between (contact zone) sand stone, clay, lignite deposit with flood basin deposit and nearby lignite mining area. Therefore, there may be significant influence of rock water interaction and anthropogenic activities.

The highest concentration was found along the north and north western area of the catchment area and the east coast of the Gadilam River Basin. These results indicated the leaching of secondary salts on the upstream side and that there may be sea water intrusion in the downstream side of the east coast study area.

Potassium (K^+) and Total Hardness (Figures 4 and 5) values are found to be in excess of the permissible values in the majority of samples in all the formations. The sequence of high concentration is as follows; Quaternary> Archaean > Tertiary. The sodium and Total Hardness values of the three formations show that the Quaternary formation has the highest value of K (100 mg/L) and TH (704 mg/L). In the Quaternary formation 94 % of the samples exceeded the limit for WHO 2017.

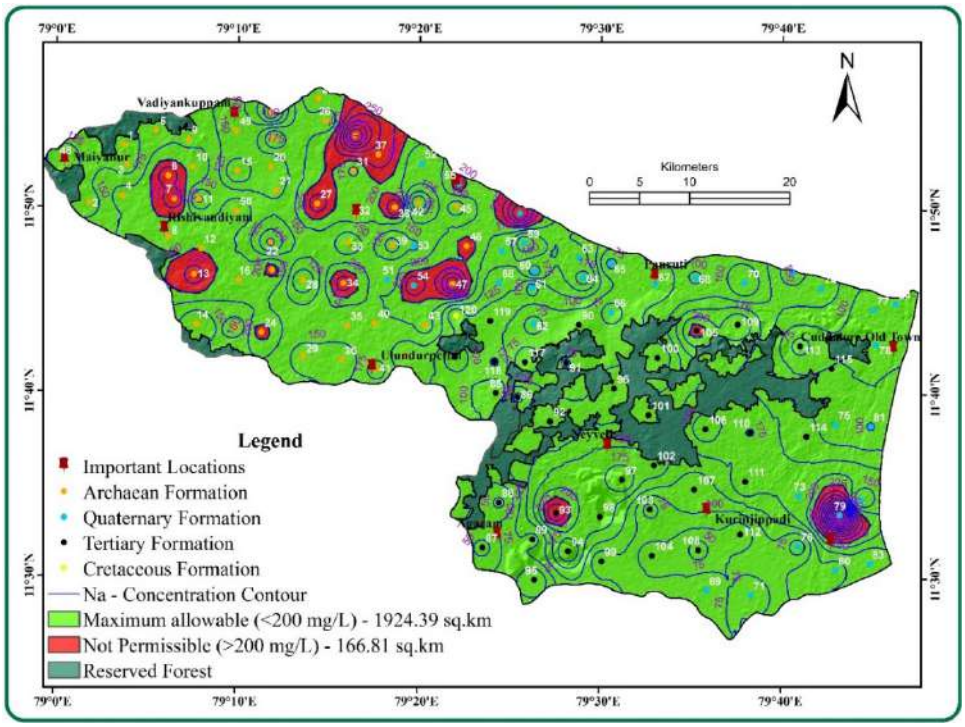

Fig. 4. Potassium spatial variation map – WHO 2017

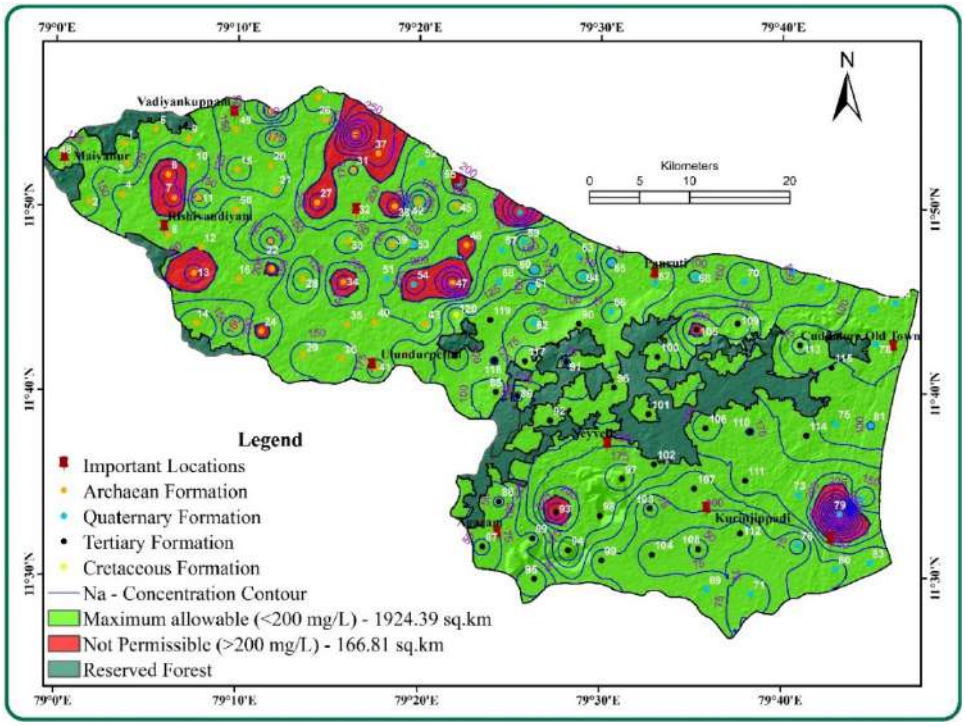

Fig. 5. Sodium spatial variation map – WHO 2017

The Archaean formation maximum value of K was 50 mg/L and TH value (684 mg/L). All the samples from the Archaean formation were observed to exceed the limit. In the Tertiary formation the highest value of K (40 mg/L) and TH 568 mg/L was noticed. The Tertiary formation groundwater quality was noticed in 89 % of the samples to be outside the permissible limit.High potassium values may cause nervous and digestive disorders (Ambrina Sardar Khan et al., 2012). The highest values are due to the greater depth of water level and high rate of evaporation during the hot season (Mahmoud et al., 2016).

Chloride (Cl^-) and Total Alkalinity (Figures 6 and 7) values are found to be not permissible in a minimum number of samples only in the Quaternary formation. The Chloride (Cl^-) and Total Alkalinity values show

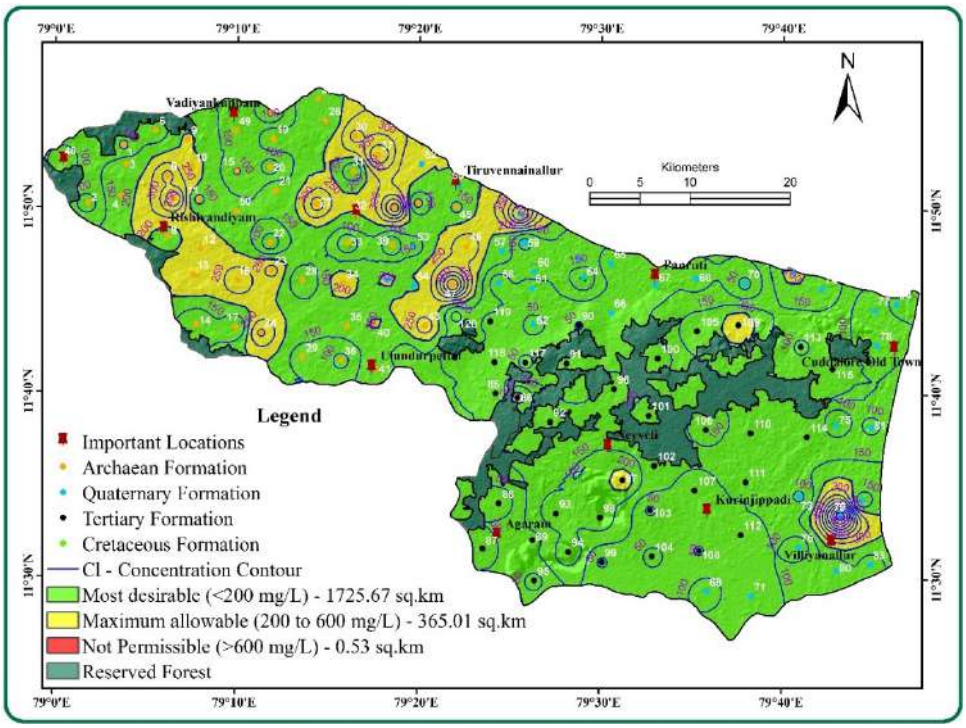

Fig. 6. Chloride spatial variation map – WHO 2017

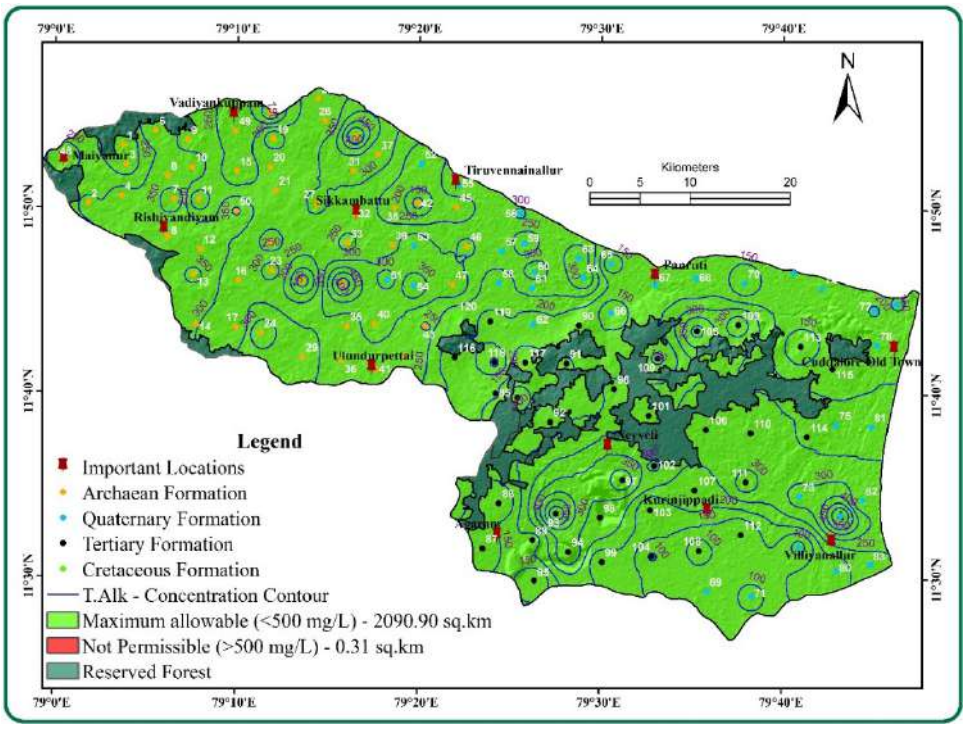

Fig. 7. Total Alkalinity spatial variation map – WHO 2017

that the Quaternary formation has the highest value of Cl^- (816 mg/l) and T.alk. (624 mg/L). Chloride (Cl^-) and Total Alkalinity values are observed to be within the limiting value for WHO 2017 in the Archaean and Tertiary formations during this season.

The higher values of Cl and Total Alkalinity were found at Periyappattu-79 (632 mg/L and 508 mg/L) station. These sample places were located on the sea shore line. There may be sea water intrusion to the fresh groundwater. The higher values were noticed in only one pocket of the shore line of the Gadilam River Basin. The rest of the section had less than 600 mg/L. The high chloride and Total Alkalinity concentration can be attributed to sea water intrusion (Sameer e al., 2011).

The EC values are found higher in some samples in all the formations. The EC values of the three formations show that Quaternary formation has the highest value (3400µmohs/cm) while the maximum value of the Archaean formation is 2600 µmohs/cm and the maximum value of the Tertiary formations is 1887 µmohs/cm. This may be due to the presence of concentrated colloids in the water (Verma et al., 2012).

From the spatial variation (Fig. 8) with contour lines of EC map, twenty-three samples in the Archaean formation are seen exceeding the limit for drinking purposes. Some of the sample places are located in between two rock types, many of the sample places are located in Hbg, there may be anthropogenic activities. Therefore, the weaker plane may have significant control on rock water interaction.

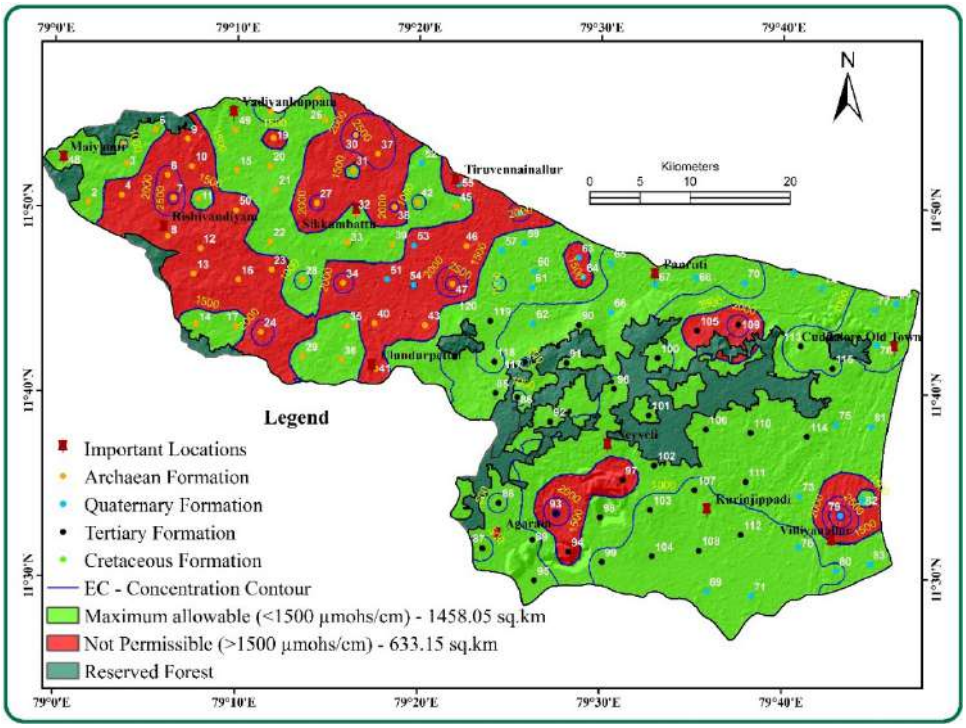

Fig. 8. EC spatial variation map – WHO 2017

Seven samples were studied from the Quaternary formation. These sample places were located in between (contact zone) the flood basin deposit with hornblende-biotite gneiss. Therefore, the weaker plain may have significant influence on rock water interaction.

In five samples from the Tertiary formation groundwater quality was found to be excess of the permissible limit. These sample places were located in between (contact zone) sand stone, clay, lignite deposit with flood basin deposit and the nearby lignite mining area. Therefore, the weaker plane may have major influence on rock water interaction and anthropogenic activities. The higher concentration occurred along the middle of the basin and east coast of the Gadilam River Basin. The rest of the area showed a value of than 1500 µmohs/cm.

Total Dissolved Solids (TDS) values were within limiting value for WHO 2017 in Tertiary formations during this season. Some samples in the other two formations were above limiting values d due to the presence of common mineral salts that are dissolved in water (Al Dahaan et al., 2016).

From the spatial variation with contour lines of TDS map (Fig. 9) two samples in the Archaean formation are seen to exceed the limit for drinking purposes,. These sample places were located in hornblende-biotite gneiss with agricultural land and in between (contact zone) hornblende-biotite gneiss and the flood basin. The reason for the high concentration may be that the weaker plain has significant influence on rock water interaction.

Only two samples were studied in the Quaternary formation. These sample places were located in between (contact zone) the flood basin deposit with hornblende-biotite gneiss. Therefore, the weaker plane may have a substantial impact on rock-water interaction.

Spatial Multi-Criteria Evaluation (SMCE) Analysis for overall Groundwater Quality

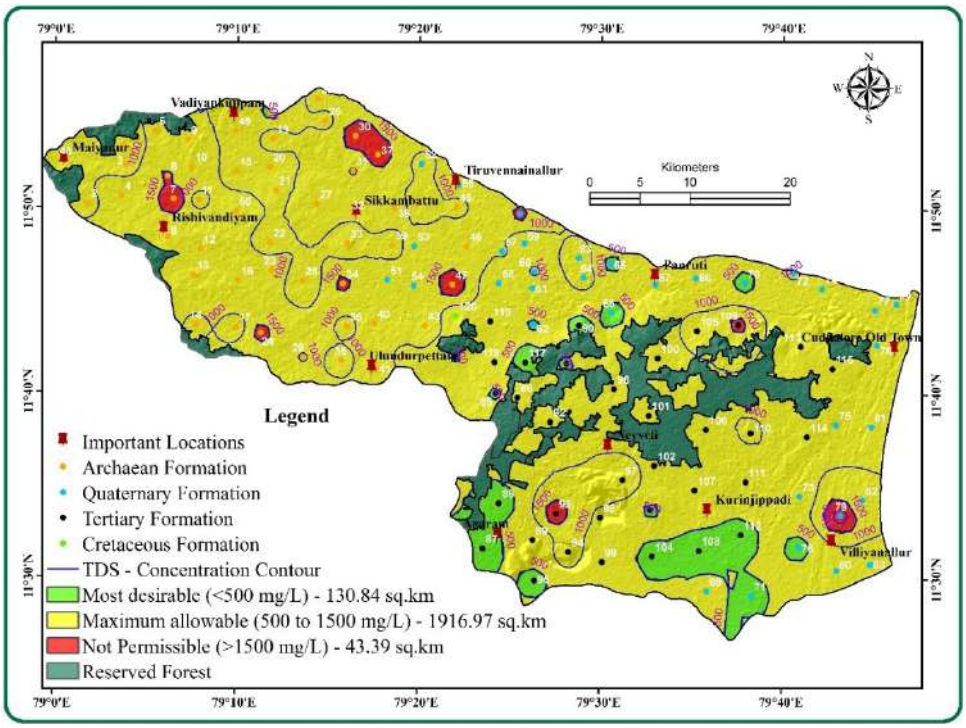

Fig. 9. TDS spatial variation map – WHO 2017

The physico-chemical parameters of contamination have a significant role in human health problems. Major groundwater quality elements were analyzed and their sources and impacts were identified using SMCE method and quality assessment. After creating the entire thematic layers based on the Table 2 Spatial Multi-Criteria Evaluation Rank of WHO 2017 standard of Groundwater, SMCE overlay analysis was conducted using all the thematic layers and finally, the locations of groundwater quality zones were mapped in the Gadilam River Basin (Fig. 10).

Table 2. Spatial Multi-Criteria Evaluation Rank on Risk Hazardous of Groundwater

Physio-Chemical Parameters	Desirable Values for WHO – 2017		Human health problems for Present Study	Spatial Multi-criteria Evaluation Rank on human health problems of Groundwater
	Most desirable limits	Maximum allowable limits		
Ca^{2+} (mg/L)	75	200	Above 200 mg/L	Within permissible limit = 0
Mg^{2+} (mg/L)	50	150	Above 150 mg/L	Within permissible limit = 0
Na^{+} (mg/L)	-	200	Above 200 mg/L	8
K^{+} (mg/L)	-	12	Above 12 mg/L	8
NO_3^{2-} (mg/L)	-	45	Above 45 mg/L	Within permissible limit = 0
Cl^{-} (mg/L)	200	600	Above 600 mg/L	8
F^{-} (mg/L)	-	1.5	Above 1.5 mg/L	Within permissible limit = 0
SO_4^{2-} (mg/L)	200	400	Above 400 mg/L	Within permissible limit = 0
HCO_3^{-} (mg/L)	300	500	Above 500 mg/L	Within permissible limit = 0
EC (µmohs/cm)	-	1500	Above 1500 (µmohs/cm	10
pH	6.5–8.5	9.2	Below 6.5 and Above 8.5	Within permissible limit = 0
TDS (mg/L)	500	1500	Above 1500 mg/L	10
TH (mg/L)	100	500	Above 500 mg/L	8
T.Alk (mg/L)	-	500	Above 500 mg/L	8
			Total Rank	60/70

Three significant factors were extracted by 'Most desirable, 'Maximum allowable' and 'Not permissible' explaining 60 of total variance (Fig. 10). Overall analysis reveals that 19 samples (Archaean-12, Quaternary-4, Tertiary-3) indicate risk of human health problems. 97 groundwater samples (Archaean-38, Quaternary-29 and Tertiary-29 and Cretaceous-1) indicate moderate risk of human health problem zones. 4 groundwater sites (Archaean-0, Quaternary-1 and Tertiary-3) are classified as No problem zones.

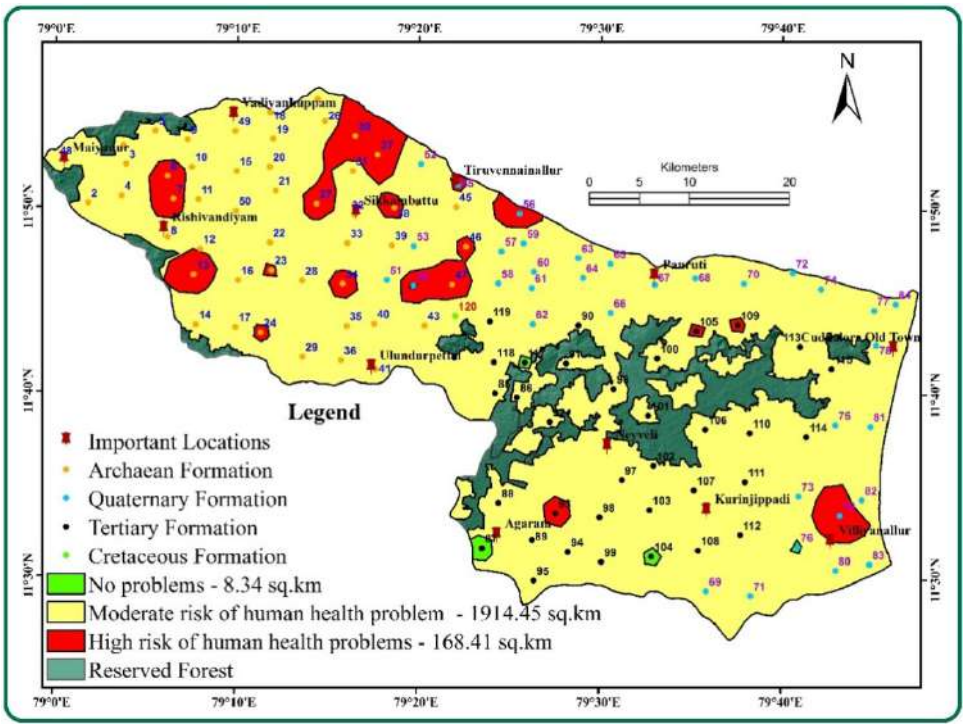

Fig. 10. SMCE Rank on human health problems of Groundwater Map

The 'Not permissible' or risk of human health problems zones were noticed in between (contact zone) hornblende-biotite gneiss and the flood basin and the reason for high concentration in the Archaean formation, it is that the Weaker plane present in the rocks may have significant influence of rock water interaction. Similarly the lineaments' intersection with the river basin and sea shore area in the Quaternary formation especially near SIPCOT industry and lignite mining area are the reason for high concentration in the Tertiary formation (Varol, 2019; Barra-Rocha, et al., 2019; Hou, et al., 2019).

Groundwater Quality Index for Irrigation.

The water quality index for groundwater samples according to formations is given below. The values of groundwater water quality index demonstrate its appropriateness for irrigation uses. The WQI can classified into five types such as Excellent (<50), Good (51–100), Poor (101–150), Very poor (151–200) and Worst (>200).

The Archaean formation WQI values are found to be less than 50 in 29 stations, which come under the category "Excellent", and 21 samples fall under the category "Good" category for irrigation uses. In order of WQI, these stations come under the category of "Excellent" and "Good" (Table 3). The Quaternary formation WQI values are observed to be less than 50 in 27 stations out of 34 locations, these stations come under "Excellent" and 7 locations fall under the category of "Good". The Tertiary formation WQI values are found to be less than 50 in 30 stations out of 35 locations, these come under the category "Excellent" and 5 stations fall under the category "Good". Overall 87 stations came under the category of "Excellent" and the stations 33 fell under "Good" in this study period (Table 3).

Table 3. Archaean Formation Water Quality Index

Formations	WQI Values – June 2019	WQI Classes	
		Excellent	Good
Archaean formation	16.49 to 85.46	29	21
Quaternary formation	16.34 to 94.97	27	7
Tertiary formation	12.44 to 78.54	30	5

From the spatial variation of water quality index map (Fig. 11) classifications of groundwater for irrigation purposes are seen. An enormous area comes under the category "Excellent". Some large patches studied in the upper part and small spots noticed in lower part of the study area come under the category "Good" for irrigation purposes. The 'Good' zones were noticed in between (contact zone) hornblende-biotite gneiss and the flood basin and the reason for high concentration in the Archaean formation, is that the Weaker plane may

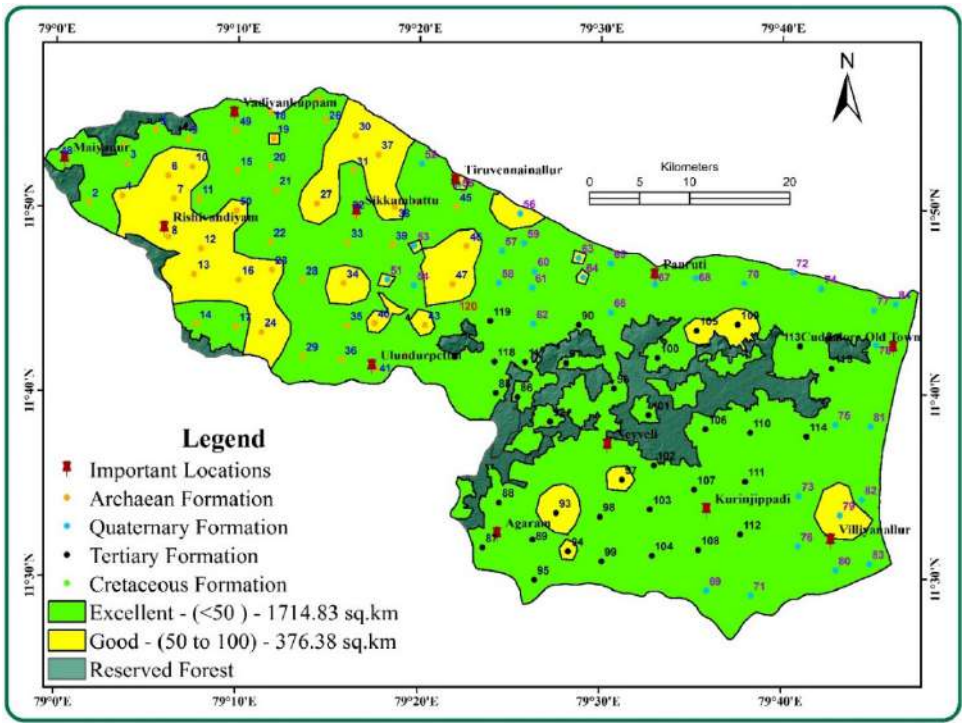

Fig. 11. Spatial variation of water quality index map

be affected by the significant influence of rock water interaction, lineaments intersection with the river and sea shore area in the Quaternary formation and by the nearby SIPCOT industry and Lignite mining area in the Tertiary formation.

Piper Trilinear Diagrams

The geochemical evaluation can be understood by six classes such as Calcium-Bicarbonate, Sodium-Chloride, Calcium-Sodium-Bicarbonate, Calcium-Magnesium-Chloride, Calcium-Chloride and Sodium-Bicarbonate types. It clearly explains the different categories of dominant cations and anions in various formations.

In the Archaean formation piper trilinear diagrams (Figures 12 and Table 4) it is observed that the majority of samples come under the No dominant type in the cation and anion triangles. A further 10 % of the stations fall under the NaCl type and rest of the stations fall under the mixed CaMgCl type. This may be due to the rock water interaction of crystalline nature of rocks and anthropogenic activities (Veena Srinivasan et al., 2014).

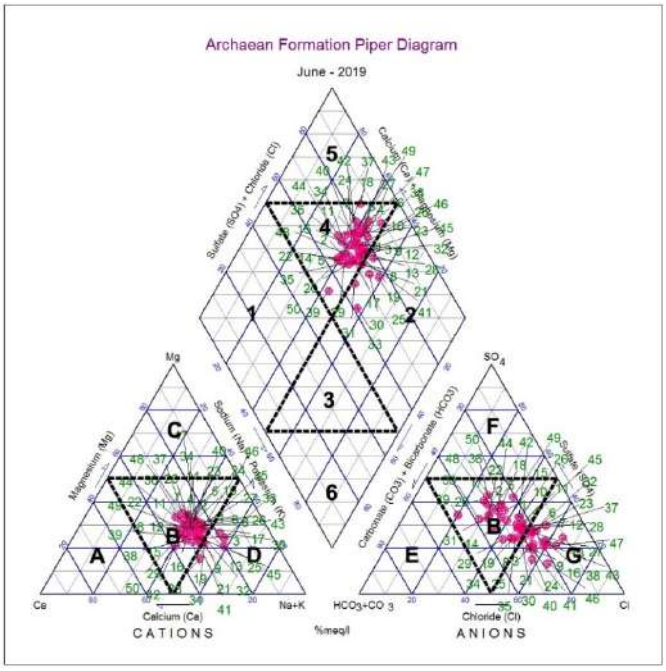

Fig. 12. Piper Trilinear Diagrams – Archaean Formation

Table 4 Piper Trilinear diagram

Geological Formations	Class No.	Class	June – 2019		
			Stations	No. of Samples	Percentage of samples
Archaean 50 Samples	1	$CaHCO_3$	Nil	Nil	Nil
	2	NaCl	25,28,30,31,33	5	10 %
	3	Mixed $CaNaHCO_3$	Nil	Nil	Nil
	4	Mixed CaMgCl	All samples except 5 samples	45	90 %
	5	CaCl	Nil	Nil	Nil
	6	$NaHCO_3$	Nil	Nil	Nil
Quaternary 34 Samples	1	$CaHCO_3$	Nil	Nil	Nil
	2	NaCl	54,55,56,57,58,60,68,70,73,79,83	11	32 %
	3	Mixed $CaNaHCO_3$	Nil	Nil	Nil
	4	Mixed CaMgCl	All samples except 11 samples	23	68 %
	5	CaCl	Nil	Nil	Nil
	6	$NaHCO_3$	Nil	Nil	Nil
Tertiary 35 Samples	1	$CaHCO_3$	Nil	Nil	Nil
	2	NaCl	86,89,90,102, 106,111	6	17 %
	3	Mixed $CaNaHCO_3$	Nil	Nil	Nil
	4	Mixed CaMgCl	All samples except 6 samples	29	83 %
	5	CaCl	Nil	Nil	Nil
	6	$NaHCO_3$	Nil	Nil	Nil
Cretaceous 1 Sample	4	Mixed CaMgCl	120	1	100 %

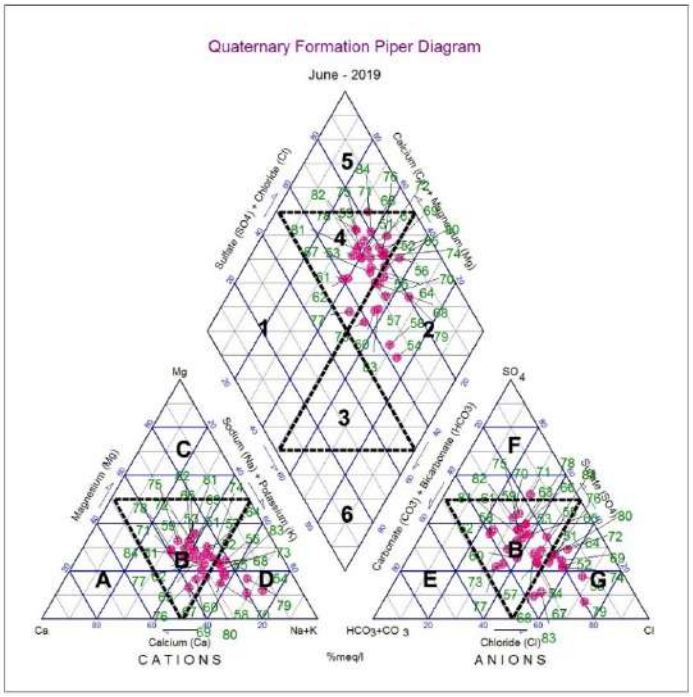

Fig. 13. Piper Trilinear Diagrams – Quaternary Formation

The Quaternary formation plots (Figures 13 and Table 4) reveals that the 32 % of the stations fall under the Sodium-Potassium type in the cation triangle and Chloride type in the anion triangle. 68 % of the stations fall under the mixed CaMgCl type. This may be due to sea water intrusion and anthropogenic activities (Vikas Tomar et al., 2012).

The Tertiary formation piper trilinear diagrams (Figures 14 and Table 4) results show that the majority of samples (more than 94 %) come under the No dominant type in the cation and anion triangles. The following stations 86, 89, 90, 102, 106, 111 fall under the NaCl type and rest of the stations fall under the mixed CaMgCl type. This may be due to the leaching of alkali salts (Umapathy et al., 2011).

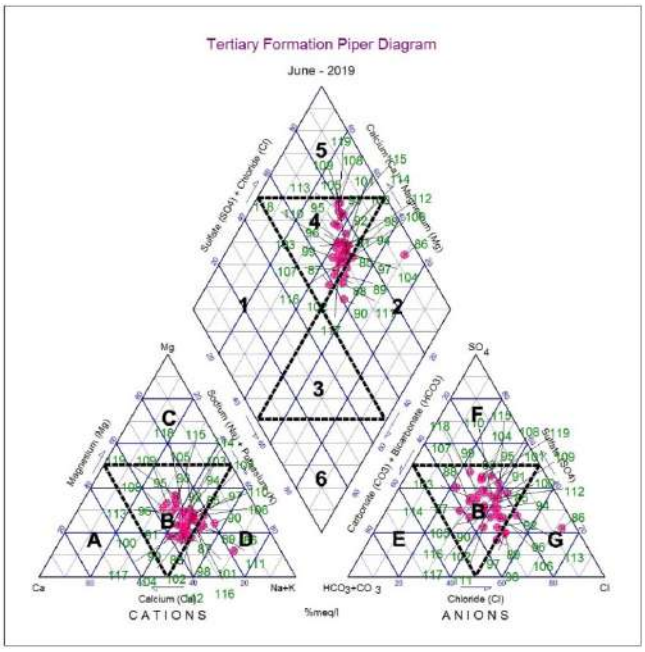

Fig. 14. Piper Trilinear Diagrams – Tertiary Formation

The Cretaceous formation piper trilinear diagrams (Figures 15 and Table 4) results show that the studied samples come under the No dominant type in the cation and anion triangles. The following stations fall under the mixed CaMgCl type. This may be due to the rock water interaction and anthropogenic activities.

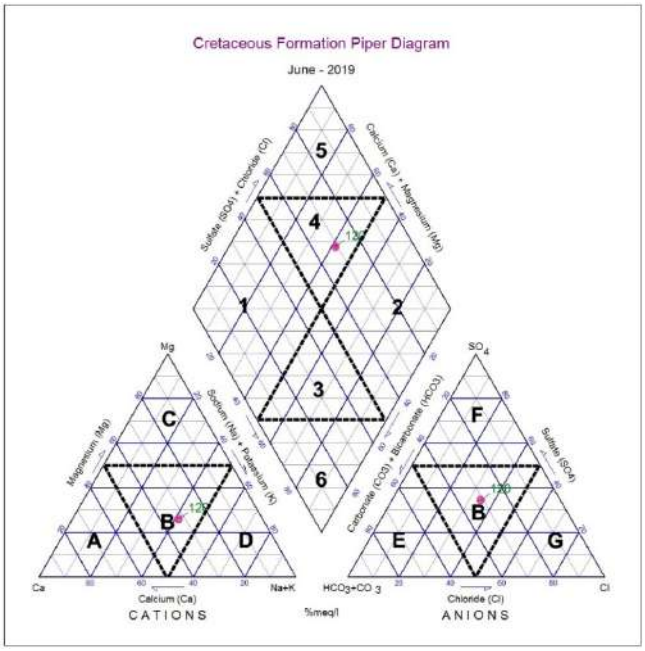

Fig. 15. Piper Trilinear Diagrams – Cretaceous Formation

Hence, this study indicates that the Piper trilinear classification of groundwater samples fall in the field of mixed Ca-Mg-Cl, and No dominance, some of the samples in Na-K, Cl types of water. So based on the Piper trilinear, the groundwater samples are fit for drinking and irrigation purposes for all formations.

Conclusions.

The highest values of the Quaternary formation physio-chemical parameters are noticed in the rainy season due to the confined aquifer (Neyveli Aquifer) containing fertilizer used in increasing agricultural activities. The groundwater quality parameters such as Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Nitrate (NO_3^{2-}),

Fluoride (F^-), Sulphate (SO_4^{2-}), Bi-carbonate (HCO_3^-) and Percentage of Hydrogen (pH) values are observed to be within limiting value for WHO 2017 in all the formations during this season.

The EC and TDS values are in excess of the permissible limit for some stations in all the formations. The TH and T. Alk.values are seen as exceeding the limit for drinking purposes among 11 samples in Archaean formation and in 2 samples in Quaternary formation.

K values are seen to exceed the limit for drinking purposes in 96 % of the samples of the Archaean formation, 74 % of the samples of Quaternary formation 94 % of the samples of the tertiary formation. The Cl, NO_3 values are exceeding the limit for drinking purposes in only two samples of Quaternary formation whereas all the samples of Archaean and Tertiary formations are within the limit.

The Water Quality Index demonstrates the appropriateness of the water for irrigation uses. The WQI values for the Archaean, Quaternary and Tertiary formations are found to be less than 100 meq/L in all stations. In order of WQI, these stations come under the category of "Excellent" and "Good".

The Piper trilinear classification of groundwater samples fall in the field of mixed Ca-Mg-Cl, and No dominance, some of the samples represent Na-K, Cl types of water. So based on the Piper trilinear, the groundwater samples are fit for drinking and irrigation purposes for all formations.

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Prerequisites of development of an accessible tourism for everyone in the European Union

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Abstract. Modern approaches of understanding the concepts of accessible tourism for everyone are analyzed in this paper. Accessible tourism for everyone means that any tourism product should be designed irrespective of age, gender and ability, and with no additional costs for customers with disabilities and specific access requirements. The role of the principles of universal design for accessible tourism for everyone is described. In contrast to the concept of accessibility, which only applies to low-mobility categories of the population and focuses on physical access to transport and premises, as well as access to information, the concept of universal design emphasizes creating the same conditions convenient for all users, without impersonating any of them. The connection between accessible tourism for everyone and the goal of sustainable development is revealed. Accessible tourism for everyone significantly contributes to the achievement most of sustainable development goals. Three main prerequisites for the development of accessible tourism for everyone in the European Union are determined and characterized by: existing accessibility legislation and standards at the global, European and national levels, population ageing and increase in the number of people with disabilities. In Ukraine there is a lack of accessibility standards for tourism facilities and services. It is important to transfer experiences and knowledge that exists in the European Union to Ukraine and ensure an adapted implementation to local requirements. A map of the most accessible cities of the European Union is created and the quantitative distribution of these cities by country of ownership is presented. Accessible to all tourism chain is analyzed on the example of Ljubljana city in Slovenia, which was twice noted by the European Commission as one of the most accessible.

Keywords: tourism, accessibility, universal design, European Union, Ljubljana.

Передумови розвитку доступного туризму для всіх у Європейському Союзі

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Анотація. У статті проаналізовано сучасні підходи до розуміння концепцій доступного туризму для всіх. Доступний туризм для всіх означає, що будь-який туристичний продукт повинен розроблятися незалежно від віку, статі і здібностей, без додаткових витрат для клієнтів з інвалідністю та особливих вимог доступу. Охарактеризовано роль принципів універсального дизайну для доступному туризму для всіх. На відміну від концепції доступності, яка застосовується тільки до маломобільних категорій населення і фокусується на фізичному доступі до транспорту і будівель, а також на доступі до інформації, концепція універсального дизайну підкреслює створення однакових умов, зручних для всіх користувачів. Виявлено зв'язок між доступним туризмом для всіх і цілями сталого розвитку. Доступний туризм для всіх вносить значний вклад у досягнення більшості цілей сталого розвитку. Визначено й охарактеризовано три основні передумови для розвитку доступного туризму для всіх у Європейському Союзі: існуюче законодавство і стандарти доступності на глобальному, європейському та національному рівнях, старіння населення і збільшення кількості людей з інвалідністю. В Україні існує проблема відсутності стандартів доступності туристичних об'єктів і послуг, тому важливо вивчати досвід Європейського Союзу і забезпечити адаптовану реалізацію до місцевих вимог. Створено картосхему найбільш доступних міст Європейського Союзу та представлено кількісний розподіл цих міст за країнами приналежності. Доступний для всіх туристичний ланцюг проаналізовано на прикладі міста Любляна в Словенії, яке двічі було відзначене Європейською Комісією як одне з найдоступніших.

Ключові слова: туризм, доступність, універсальний дизайн, Європейський Союз, Любляна.

Introduction.

The European Union (EU) is the main tourist destination in the world. Four EU member states (France, Spain, Italy and Germany) belong to the top ten countries of the world upon arrival of tourists. The EU population is ageing. Considering the whole population,

the number of elderly people represented by the 65+ age group is above 88 million, which means that every 5th person belongs to this demographic group (Zsarnoczky, 2017). It is forecasted that in 2050 approximately 35 % of the population in developed countries will be at least 60 years old. Unlike past generations, today's seniors are seeking a more active and adventurous lifestyle for their post work lives. Tourism is an important component of their quest for life experiences. With the ageing of the baby boomer generation and their accompanying burden of disease, future disability rates are expected to increase (Bowtell, 2015).

Senior citizens and people with disabilities together represent a demographic group with significant economic importance within the EU (Zsarnoczky, 2017). The general demand for accessibility in Europe alone exceeded 120 million people in 2005, more than 27 % of the European population at the time. It is estimated that by the end of 2025 this demand will reach about 160 million people (Bowtell, 2015) 1. The accessible tourism market in the EU is estimated at approximately 12 % of the whole tourism market (UNWTO, 2016b). It includes tourists with varying levels of accessibility requirements who have been poorly served by the tourism industry in the past. An analysis of the accessible tourism market size shows that 70 % of the population demanding accessibility have the financial as well as the physical capabilities to travel, generating potential revenues of 88.6 billion euro by 2025 (Bowtell, 2015). Accessible tourism's direct economic impact was approximately 352 billion euro in 2012, while its overall contribution, given indirect and sub-contracted amounts, is estimated at 800 billion euro. This represents around 3 % of the EU 28's GDP. The accessible tourism market directly provided 4 million jobs, with multiplying effects creating a total of 9 million jobs in the EU (UNWTO, 2014). Europe and its tourism sector are very urbanized. Hence, European cities play an important role in ensuring adequate access for both citizens and tourists of all ages and capacities. Many European cities are working to build their reputation as accessible, livable cities that offer hospitality to all visitors. Therefore, it is of great importance to study their geography and the best practices of accessible tourism for all people.

The purpose of this study is to analyze the prerequisites to develop an accessible tourism for everyone in Ukraine. The EU serves as a model, with a more extensive consideration of the accessible tourism chain concept of Ljubljana (Slovenia). Tasks of this study are:

- to consider the modern approaches of understanding the concepts of accessible tourism for everyone;
- to evaluate the prerequisites for the development of accessible tourism for everyone in the EU;
- to depict cartographically the accessible cities of the EU, as well as the quantitative distribution of these cities by country of affiliation;
- to analyze the accessibility of the tourism chain on the example of the Ljubljana city in Slovenia.

Methodology and methods.

In general, qualitative methodology is mainly used in tourism, which is also reflected in this study. A review of relevant, existing academic research as well as statistics, legislation, manuals and reports were undertaken to inform the methodological development of the study, providing a wider overview of the matter under study and identifying the need for further research. The study used publications and data of the World Tourism Organization (UNWTO), the European Commission (EC), Eurostat and the European Network for Accessible Tourism (ENAT). It widely applies the method of analyzing documents, in particular the Global Code of Ethics for Tourism, the UN Convention on the Rights of Persons with Disabilities, the European Law on Accessibility, State Building Codes of Ukraine etc. Various statistical data (provided by Eurostat[2]) are analyzed in order to evaluate the aging of the population and the growth of people with disabilities in the EU as important prerequisites for the development of accessible tourism for everyone. A cartographic method is used to carry out a spatial analysis of accessible tourism, the most accessible according to EC Award cities are depicted on a map. The distribution of these cities by country of affiliation is shown in the diagram. The Access City Award is one of the measures foreseen in the EU Disability Strategy 2010–2020. It is co-founded by the EC in conjunction with the European Disability Forum and aimed to create a Europe without barriers for people with disabilities (EC, 2010). The award identifies cities that are leaders in overcoming the barriers in Europe today and is given to the nominee that noticeably improved accessibility in the main aspects of urban life. This includes the building-up of environment and public space, transport and related infrastructure, information and communication technologies, public facilities and services. The respective cities also must strive for continuous improvement of accessibility on an ongoing basis and can serve as a role model for best practices in other European cities. Thus, the competition covers the accessibility in the daily life of

[1] This and the following information about future developments of tourism provided by Bowtell (2015) include data for Great Britain that left the EU in 2020.

[2] This and the following information provided by Eurostat (2015) include data for Great Britain that left the EU in 2020.

city residents, and, to a certain extent, the accessibility of tourism offers (EC, 2018a).

The accessible tourism chain of Ljubljana basing on the UNWTO (2013) recommendations indicate the appropriate measures in order to ensure that persons with disabilities have access on an equal basis. This contains the physical environment, transportation, information and communications (including computer systems, information and communication technology) and other services and facilities open to the public or for public use. This applies to urban areas as well as rural and coastal zones. This is shown in detail below.

National, regional and local tourism authorities should evolve accessible tourism development strategies. It is necessary to ensure that tourism facilities or accommodation facilities located in regions without an accessible transport system, an appropriate environment and communication with other tourism facilities cannot advertised as accessible.

Travel literature and other promotional materials must contain clear information about the accessibility of services and amenities, preferably using international characters that are easy to understand. Wherever possible, information for people with disabilities should include general information materials. Promotional materials need to comprise information on how to contact the organization through accessible means of communication and whether it is possible to receive promotional materials in an alternative format. In places where tourists are welcomed, a list of all support services for tourists with disabilities should be available. Booking systems should be accessible in a way that any tourist can use them independently. Due to this, booking systems should be developed in accordance with the "Guide to the accessibility of web content" (WCAG).

Key indicators of the accessibility of urban environment and architecture include:

- Parking spaces (containing specially equipped and designated parking lots for people with mobility impairment, boarding as well as disembarking of tourists to and from transport);
- Information and communication systems (including the use of sign language, Braille, the presentation of texts in large print, the use of pictograms and symbols, visual and sound announcements etc.);
- The possibility of free horizontal movement (due to the standard width of doorways, corridors, no thresholds, accessibility tactile, visual and sound elements of accessibility for people with visual impairments);
- Vertical movement (elevators, stairs, ramps are equipped in accordance with the norms);
- Sanitary facilities of general uses;
- The price (do not provide high prices to ensure the accessibility of facilities services).

Passenger transport, including rental cars, buses, taxis, trams, funiculars, trains, ferries and cruise ships should be designed to be safe, comfortable and equally accessible to all people. Before and during the trip it is necessary to take the needs of people with hearing and visual impairments into account. Information should be presented in audio and visual format for them. Especially pedestrian crossings need to be equipped with traffic lights that have visual and audible warning.

Accommodation facilities should offer enough rooms equipped for people with disabilities. The design of all devices and mechanisms must comply with the principles of universal design. In such establishments, visitors with guide dogs must be accommodated appropriately. There should be a sufficient number of restaurants, cafes and bars with accessible conditions close to such buildings. This has to include accessibility to the premises, furniture design that takes the needs of people with reduced mobility and strollers into account, a lowered counter, a Braille menu (or an alternative format), accessible toilets, etc. The menu must include dishes for people with food restrictions (lactose or gluten intolerance), or beliefs (e. g., veganism or vegetarianism). Conference rooms should be equipped with special places or zones for accommodating guests using wheelchairs, headphones for audio-descriptive commenting on the use or amplification of sound as well as induction loops for people using hearing aids. It must be ensured that audiovisual information can be supplemented by audio description, subtitles or sign language translation if necessary.

Museum owners or administrators must ensure that their institutions are fully accessible to visitors with disabilities (e. g., with lifts and ramps). Information should be provided in both visual and audio format. Visitor staff must receive the necessary training to serve visitors with disabilities. A rental service for strollers or other equipment should be provided for visitors with reduced mobility.

Understanding the concepts of accessible tourism for all people. The Global Code of Ethics for Tourism (GCET) promotes the right of all people to equality in access the resources of the planet. This is the main postulate of the concept of accessible tourism for everyone (UNWTO, 1999). Accessibility is a fundamental feature of the built environment. Accessibility allows people to participate in social and economic activities for which the built environment has been created (ENAT, 2007a). The concept of accessibility is used primarily in the interests of people with limited mobility, which includes seniors, people with disabilities and temporary health problems or chronic diseases, as well as accompanying children in wheelchairs. These categories are considered by Ukrainian law since April 1, 2019 when the new

State Building Codes "Inclusiveness of buildings and structures" entered into a force. These Ukrainian codes don't fully comply with EU-law because they don't account for the children that are younger than seven years, people with non-standard body sizes and weights as well as some others. In the field of tourism, the following types of accessibility should also be considered legally (ENAT, 2007b):

- Physical accessibility (creation of a barrier-free environment in buildings, structures, transport);
- Communication and information accessibility (including accessibility of websites, information products, signage, a multiplicity of communication methods etc.);
- Accessibility of services (awareness of staff on disability, communication methods and services for people with various types of disabilities, various age groups etc.).

Accessibility is one of the signs of a "smart city". Implementing innovative solutions based on the principles of universal design, the "smart city" is turning into a "smart city for everyone" (AT & T, 2017). A smart city characterizes itself by accessible websites, transportation systems and accommodation facilities, catering services, program offers, local information, a safe environment, professional service providers and staff (Zsarnoczky, 2017). From the geographical perspective, the accessibility of tourism space was once understood in terms of accessible transportation – to get to a specific destination. It also included transportation links, hiking trails and ski lifts within touristic destinations. Geographers also noted the meaning of accessibility represented by the concept of hospitable space, identifying hospitable tourism space as that which is attractive, accessible, safe and friendly (Zajadacz, 2014).

A good design is an important condition for accessibility. People refer to this kind of design with terms such as Design for everyone or Universal Design. Universal design means that the design of products, environments, programs and services is usable by all people, to the greatest extent possible, without the need for adaptation or specialized design (UN, 2007). This designing concept includes the following principles:

- Equitable use (the design is useful and marketable to people with diverse abilities);
- Flexibility in use (the design accommodates a wide range of individual preferences and abilities);
- Simple and intuitive use (use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level);
- Perceptible information (the design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities);
- Tolerance for error (the design minimizes hazards and the adverse consequences of accidental or unintended actions);
- Low physical effort (the design can be used efficiently and comfortably and with a minimal tiredness of fatigue);
- Size and space for approach and use (appropriate size and space is provided for approach, reach, manipulation and use regardless of user's body size, posture, or mobility).

In addition to ensuring the rights of people with limited mobility, universal design creates conditions for gender equality. That's why the concept of universal design emphasizes creating the same conditions that are convenient for all users, without impersonating some of them. Whereas the concept of accessibility applies only to people with limited mobility and focuses mainly on issues of physical access to transport, buildings and structures, as well as access to information. According to universal design, accessibility must be introduced from the beginning, considering the design, instead of waiting to improve it once products and services have been created (ENAT, 2007a).

In modern literature the concepts of "inclusive tourism", "social tourism", "sustainable tourism" and "accessible tourism" are also used. Often all these concepts are identified, which is wrong. *Inclusive or social tourism* are the concepts that incorporate the rights of underprivileged people, often including disabled people, to enjoy their holidays (Buj, 2010). *Sustainable tourism* is involved in the protection of environmental and cultural resources and the wellbeing of communities (UNWTO, 2016a). As defined by the World Committee on Tourism Ethics (WCTE, 2014), accessible tourism for everyone means that any tourism product should be designed irrespective of age, gender and ability and with no additional costs for customers with disabilities and specific access requirements. Accessible tourism takes the full human life cycle into account. It additionally considers the fact that anyone can benefit from certain types of facilities, depending on their physical condition (which can change) and the stage of someone's family life. Problems of restricted access to tourism space (due to physical, technical, social, information-based, economic barriers) affect many social groups. That includes people with a disability, elder people, families with young children and those at risk of social exclusion (e. g., immigrant families, the poor, ethnic or religious minorities; Zajadacz, 2014). Accessible tourism requires a joint approach across the tourism supply chain (i. e., transport, accommodation, leisure activities, hospitality, destinations) to ensure a positive tourism experience. Elderly people and people with disabilities get the

greatest benefit from accessible tourism because they face the strongest obstacles through an inaccessible environment. However, people of different ages and with different opportunities can benefit from accessible tourism for everyone. The target group of accessible tourism is not limited only to tourists; it also includes tourism workers and creates employment opportunities for people with disabilities (ENAT, 2007a).

Accessible tourism significantly contributes to the achievement of most of the sustainable development goals (SDG). This applies above all to SDG 10 (Reduced inequalities), SDG 11 (Sustainable cities and communities) and SDG 17 (Partnerships for the goals; UNWTO, 2017).

Main prerequisites for the development of accessible tourism for everyone in the EU. The main prerequisites for the development of accessible tourism for everyone in the EU now and in the future will be an aging population (Fig. 1), an increase in the number of people with disabilities and state of the legislative framework on accessibility.

Elderly people are motivated to travel by different motives like visiting relatives, getting cultural or gastronomic experience. They are interested in cruise ship trips, coastal holidays, participation in sporting events or ethnic holidays. They tend to spend more while traveling and stay longer. Baby boomers who were born in 1946–1964 are the dominant travelers in the world. They are becoming more and more adventurous in the choice of travel, in search of new experiences and active types of recreation. Another type of old age tourists is a flashpacker who is not faced with the task of various cost savings, but the main principles is the freedom of movement and maximal experience – remains unchanged. The largest share of elderly people was observed in the population structure of Italy, Greece, Germany, Portugal, Bulgaria and Finland (Eurostat, 2017).

Tourists with disabilities make travel decisions based on the opinions of their friends and rely less on special offers aimed at them. Travel agencies' online offers and printed brochures influence their decision on the same level. France and the UK have the most people with disabilities in the EU (Eurostat, 2015).

In this study the existing legislative framework on accessibility in the EU is considered at three levels: global, European and national. The main documents regulating accessibility issues at the global and European levels are for examples UN Convention on the Rights of Persons with Disabilities, Global Code of Ethics for Tourism etc.

Regulatory acts that are applied at the European level with specific requirements for accessibility of services for persons with disabilities include (ONCE, 2009):

- European Regulation on the Rights and Obligations of Railway Passengers;
- European Regulation on the Rights of Persons with Disabilities and Persons with Disabilities Traveling by Air;
- EU Maritime Safety Directive;
- European Lift Directive etc.

Making Europe accessible to people with disabilities was a key part of the EU's overall disability strategy for 2010–2020. This Strategy provided an EU-wide framework for action on disability and accessibility to complement and support member states. On November 8, 2018, the European Parliament and the Council tentatively agreed with the EC proposal for a European accessibility law. This law will cover the following products and services (EC, 2018): computers and operating systems, ATMs phones and smartphones, television equipment related to digital television services, audiovisual media services, services related to air, bus, rail and water passenger transport, banking services, eBooks as well as e-commerce. The law will establish pan-European functional requirements for the accessibility of the listed products and services. However, the tourism facilities are not represented here at all and tourism services are represented only indirectly. The current absence of common accessibility standards in the EU can be considered a consequence of its historical development, when countries and regions continue to practice their sovereignty in this area, based on the legal principle of subsidiarity – this also includes tourism.

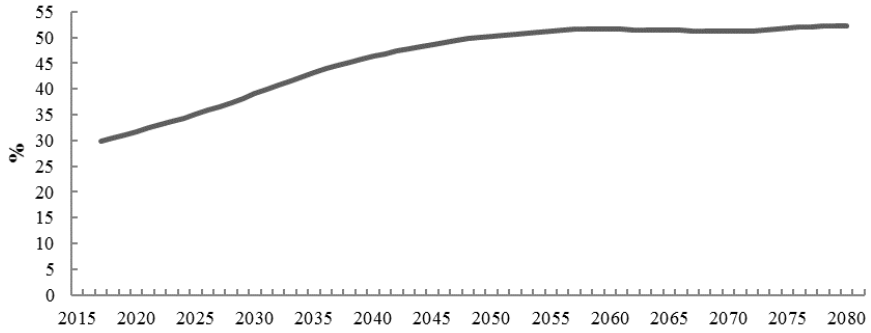

Fig. 1. Forecast of the demographic burden of an aging population (65 years and older) on the working age (15–64 years) in the EU (Source: Eurostat)

The impetus for accessible tourism for all people from the EU was the preparation of the EC Guidelines for the tourism industry under the title "For Accessible Europe, for Tourists with Disabilities" (1996) and the adoption of the Regulation of the European Socio-Economic Committee entitled "For accessible and socially sustainable tourism for everyone" (ENAT, 2007a).

The following accessibility tools for tourists are used at national level in EU countries (ONCE, 2009):

- National laws on non-discrimination of persons with disabilities;
- National or community accessibility standards;
- National standards for the accessibility of tourism facilities;
- Regional legislation and / or accessibility standards for tourism facilities;
- National or regional information accessibility systems (and labeling) for tourism facilities managed by government agencies;
- Labeling schemes managed at the regional or national level by private tourism organizations;
- Participation of national representatives (authorities, manufacturers or consumers) in the work according to international accessibility standards.

We give two examples according to which the Standards relating to the rights of people with disabilities, accessibility and design for everyone can directly affect the tourism industry. One type of regulation is centralized, like in the United Kingdom. There only one law exists – the Law on the Prevention of Discrimination of Persons with Disabilities, which equally regulates the actions of travel providers in terms of accessibility and design for everyone throughout the country. Another example is decentralized regulation, like in Spain. There each autonomous region sets its own laws to regulate tourism and accessibility. In practice, this means different levels of accessibility in the tourism industry of each of these regions (ENAT, 2007a).

On the way to integration into European and world communities, Ukraine ratified several international legal acts that had a certain impact on the formation of national state policy, the granting of equal opportunities for all citizens and the introduction of principles of accessibility of persons with disabilities. Most of these acts are transformed into national legislation – for example the national law called "On the Basics of Social Protection of Persons with Disabilities" (Zakon Ukraiiny…, 2020). In addition, the following Ukrainian laws have been adopted to regulate the legal status of certain groups of persons with disabilities and to ensure accessibility principles (Azin, Baida, Hrybalskyi, Krasiukova-Enns, 2013):

- On Social Services;
- On the Regulation of Urban Planning Activities;
- On Access to Public Information;
- On Protection of Consumer Rights;
- On Transport;
- On Amending Certain Legislative Acts of Ukraine Regarding Strengthening Responsibility and Improving State Regulation in the Sphere of Urban Development.

Furthermore, the topic is promoted by several decrees by the President of Ukraine and decisions of the Cabinet of Ministers of Ukraine. Some of these documents support the participation of representatives of public organizations of people with disabilities in the preparation and adoption of decisions that affect their lives.

In April 2018, the Ukrainian government approved three new State Building Codes – "Planning and development of territories", "Streets and roads" as well as "Buildings and structures. Educational institutions". All buildings and structures in Ukraine must be designed with accessible elements. This also includes the necessary infrastructure. The introduction of these standards is a significant step towards creating a real barrier-free environment in Ukraine and one of the priority requirements in connection with the ratification of the UN Convention on the Rights of Persons with Disabilities and the Association Agreement with the EU. However, the problem of insufficient standards for the accessibility of tourism facilities and services in Ukraine remains relevant. In this regard, it is important to study the experience of individual EU countries where such standards exist.

Spatial analysis of accessible tourism for everyone in the EU. The cities of the EU, which, according to the EC, are trying to maximize accessibility, are presented on the Fig. 2. Most of these cities were in France (4), Germany (4) and Sweden (3)[3]. With 23 of the most accessible cities, only five are state capitals. At the same time, the city of Ljubljana in Slovenia was twice marked by the EC as one of the most accessible cities. Among the 23 most accessible cities in the EU, six are known for sea resorts. In addition to the cities that took first, second and third places, there are also cities with "special notes". For example, the city of Budapest (Hungary) received an award for actions in the field of transport in 2015. The city of Bilbao (Spain) received an award for actions in the field of information and communication in 2013. The city of Talla (Ireland) received an award for actions in the field of public institutions and services in 2013. The city of Viborg (Denmark) received an award for actions in coordinating the historical heritage and the hilly landscape with accessible infrastructure in 2018. The city of Toulouse (France) was noted as a "smart city" in 2018.

[3] The displayed data comprise the years 2011–2018.

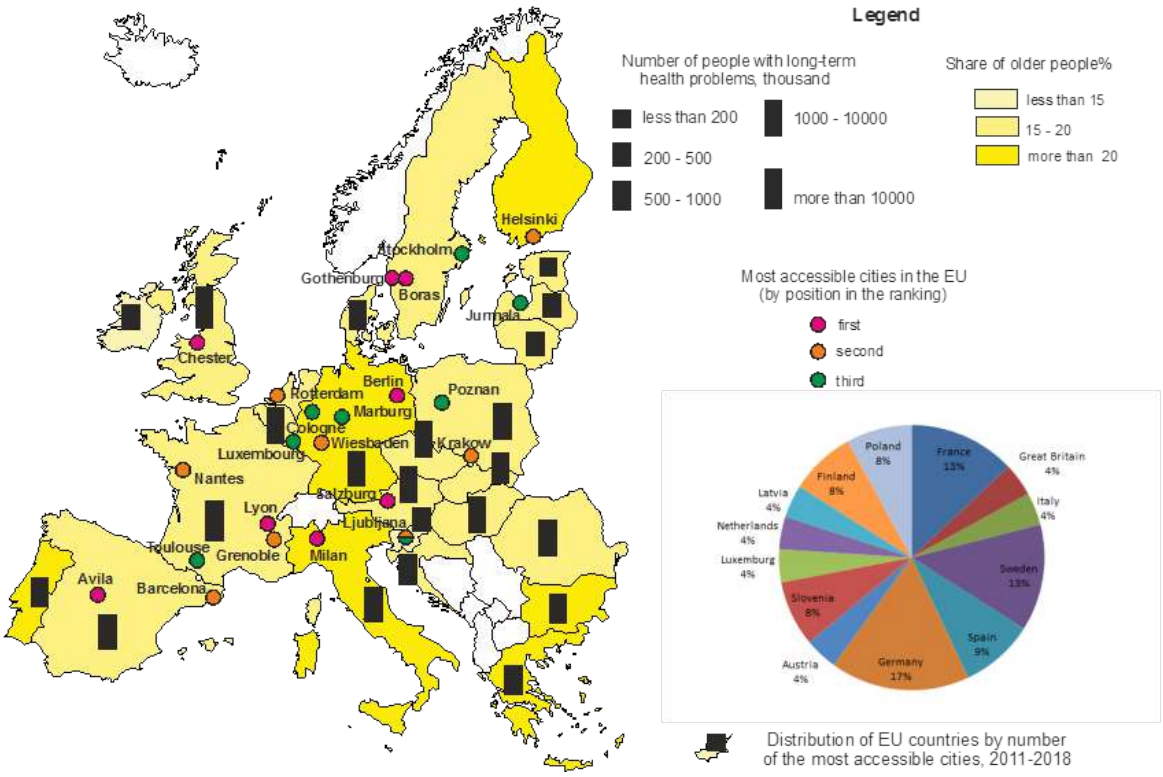

Fig. 2. Geography of the most accessible cities of the EU in 2011–2018

Accessible tourism chain in Ljubljana city

Ljubljana was the finalist of the EU Access City Award for the year 2018 (2nd prize) and 2015 (3rd prize), where it was recognized as an accessible city, actively developing accessibility and with strong commitment at political and operational levels. Accessibility is integrated in overall city policy and work (EC, 2018a). The most important points are summarized below:

Tourism destination management

Monthly open-day-meetings with the mayor to listen to people's suggestions for improvement, including accessibility issues. Direct involvement of elder and disabled people in city policymaking through mayoral advisory bodies which offer advice on priorities for access improvements both to the city authorities and to private sector providers. Action plans for improving accessibility with clear deadlines and concrete objectives. Improvements of accessibility are combined with sustainability issues (Ljubljana as named European Green Capital in 2016; Elevator, 2015).

Tourist information

A city map of accessible locations is available. A specialized tourist city centers provide the information for visitors over 65 and those with a disability.

Transport

All the city's buses are low floor with space for wheelchair users, almost everyone with boarding ramps and with audible and visual on-board announcements. The main railway station is equipped with elevators, with support from trained staff for access to platforms. Travel is free for disabled residents and their careers. A system of unique identification cards means that assistance can be provided quickly if needed during a journey. A demand responsive service, which users can call when they want it, is available for those who need door-to-door transport.

Accommodation

Many hotels in Ljubljana are convenient and friendly for persons with reduced mobility and disabled people. They offer easy access for wheelchairs, wheelchair accessible rooms and bathrooms.

Cultural establishments and destinations

Sign language is used in theatres, tactile exhibits and maps (for example in the castle). Adapted videos, multisensory guiding and easy-to-use information are offered. Access to the castle is provided via a funicular railway and a tourist train equipped with a ramp. A tactile model of the castle is also available for visually impaired people. In addition to many new footbridges over the river, the "Mesarski most" (Butcher's bridge) provides wheelchair access to boats.

Public Places

Slovenian laws regulate the presence of accessible services. Thanks to this, parking spaces for disabled are generally available. The city's public toilets are free of charge and currently ten out of 19 are accessible.

Staff

There is a wide range of initiatives to promote both open and sheltered employment opportunities. One example of social entrepreneurship is the restaurant

"Druga Violina" (Second Violin) in the old city center where people with intellectual disabilities participate in a real work environment. A course about accessible tourism is available for restaurateurs, hotel staff and travel guides.

Conclusions.

Accessible tourism for everyone means that any travel product must be designed oriented to different customers in mind and be accessible regardless of age, gender, disabilities or restrictions, without any additional costs. Accessibility should be integrated into all links of the tourism chain: booking, providing information, transportation, accommodation, food, accessibility of historical monuments and excursions, accordingly trained personnel and the like. The concept of accessibility only applies to people with limited mobility and focuses mainly on issues of physical access to transport, buildings and structures as well as access to information. In contrast, the concept of universal design emphasizes the creation of the same conditions that are convenient for all users, without impersonating some of them.

Elderly people and people with disabilities can obtain the greatest benefit from accessible tourism because they face the greatest obstacles through an inaccessible environment. The main prerequisites for the development of accessible tourism in the EU are an aging population and an increase in the number of people with disabilities. The state of the legislative framework on accessibility is also an important prerequisite for the development of accessible tourism. For Ukraine, it is important to study the experience of individual EU countries, their standards for accessibility of tourism facilities and services. Many European cities are working to build their reputation as accessible, livable cities that offer hospitality to all visitors. Most of these cities are located in France, Germany and Sweden. Ljubljana city in Slovenia was twice awarded by the European Commission as one of the most accessible.

In the future, subsequent studies will be based on a quantitative and qualitative survey among five types of stakeholders, developing five types of questionnaires. This includes:

- Accommodation providers (including owners or managers of hotels, hostels, caravan parks, cruise companies etc.);
- Airport managers (including managers who work for the airport owner or managers from companies that are contracted to manage passengers and ground handling operations);
- Destination and attraction managers (including managers of city tourism marketing offices, museums, sports venues, leisure and amusement parks, national parks, heritage sites etc.);
- Access experts;
- Visitors with access needs.

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Spatially distributed assessment and forecast of soil erosion losses as a basis for optimization the use of erosion-hazardous agricultural lands

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Abstract. The article is devoted to the problem of sustainable use of agricultural lands in conditions of active manifestation of water soil erosion, which is typical for all natural zones of Ukraine, but to the greatest extent – for the Forest-Steppe and Steppe zone. The aim of the article is a spatially distributed quantitative assessment and forecast of soil erosion losses and the development on this basis of recommendations to optimize the use of agricultural land on the example of the Pidhayetskyi district of the Ternopil region. The area is located within the Western region of Ukraine with a fairly high intensity of water erosion, where in accordance with the long-term climate forecast a further increase in erosion hazard of land is expected. A quantitative assessment of soil erosion losses for the basic period (1961–1990) and forecast periods (2031–2050 and 2081–2100) was carried out using a spatially distributed physical-statistical GIS-model of soil erosion-sedimentation developed at the Department of Physical Geography, Nature Management and Geoinformation Technologies of Odesa I. I. Mechnikov National University. Spatial realization of the model performed using the analytical capabilities of the Software for Environmental Modeling PCRaster (University of Utrecht, Netherlands). The forecast of the changes in the hydrometeorological conditions of water soil erosion was made using the forecast of monthly average air temperatures and monthly average precipitation, developed at the Ukrainian Hydrometeorological Institute. It established that most of the arable land (about 52 %) of Pidhayetskyi district is erosively dangerous. Due to the projected increase in summer rainfall in the middle and at the end of this century, further intensification of soil erosion is expected, especially in 2031–2050, when soil losses on arable land will increase to 16.9 t/ha/year, and only due to rainstorm erosion. Soil losses by meltwater will be insignificant. Based on the calculations, it was concluded that it is impossible to protect the agricultural lands of the region from erosional degradation without withdrawal from the arable land about 8.15 thousand hectares (28) of the most erosion-hazardous lands (with annual soil losses exceeding 20 tons per a hectare), changing the structure of sown areas and introduction a soil-protective adaptive-landscape farming system over a significant area.

Ключові слова: soil erosion, spatially distributed assessment and forecast, optimization of land use, Pidhayetskyi district, Ternopil region.

Просторово-розподілена оцінка і прогноз ерозійних втрат ґрунту як основа оптимізації використання ерозійно-небезпечних земель

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Анотація. Стаття присвячено проблемі раціонального використання сільськогосподарських земель в умовах активного прояву водної ерозії ґрунтів, характерного для всіх природних зон України, але найбільшою мірою – для Лісостепу і Степу. Метою статті є просторово-розподілена кількісна оцінка і прогноз ерозійних втрат ґрунту і розробка на цій основі рекомендацій щодо оптимізації використання сільськогосподарських земель на прикладі Підгаєцького району Тернопільської області. Район розташований в межах Західного регіону України з досить високою інтенсивністю водно-ерозійної діяльності, де відповідно до довгострокового кліматичного прогнозу очікується подальше збільшення ерозійної небезпеки земель. Виконана кількісна оцінка ерозійних втрат ґрунту для базового періоду (1961–1990 рр.) і періодів прогнозу (2031–2050 і 2081–2100 рр.) з використанням просторово розподіленої ГІС-реалізованої фізико-статистичної моделі змиву-акумуляції ґрунту, розробленої на кафедрі фізичної географи, природокористування і геоінформаційних технологій Одеського національного університету імені І. І. Мечникова. Прогноз зміни гідрометеорологічних умов водної ерозії ґрунту виконано з використанням прогнозу середньомісячних температур повітря і середньомісячних сум атмосферних опадів, розробленого в Українському гідрометеорологічному інституті. Встановлено, що більша частина орних земель Підгаєцького (близько 52 %) району є ерозійно небезпечною. У зв'язку з прогнозованим збільшенням кількості літніх опадів в середині і в кінці поточного сторіччя, очікується подальша інтенсифікація ерозії ґрунтів, особливо в 2031–2050 роках, коли середньорічні втрати ґрунту на орних землях району збільшаться до 16,9 т/га/рік, причому тільки за рахунок зливової ерозії. Втрати ґрунту талими водами будуть практично не значущими. На основі виконаних розрахунків зроблено висновок про неможливість захисту орних земель району від ерозійної деградації без виведення зі складу ріллі близько

8.15 тис. га (28 %) найбільш ерозійно небезпечних земель, зміни структури посівних площ і впровадження на значній площі ґрунтозахисної адаптивно-ландшафтної системи землеробства.

Ключові слова: водна ерозія, просторово-розподілена оцінка і прогноз, оптимізація землекористування, Підгаєцький район Тернопільської області.

Introduction.

Comprehensive protection of agricultural land from water soil erosion common in all natural zones of Ukraine can be ensured only on the basis of the use of adaptive-landscape farming systems, such as contour-reclamation, landscape-ecological, precise (Shelyakin et al., 1990; Tarariko, 1990; Kashtanov et al., 1994; Magleby et al., 1995; Bulygin and Nearing 1999; Tarariko, 2005; Vergunov, 2006; Montgomery, 2007; Hobbs et al., 2008; Rykhlivskyi et al., 2014, etc.). The design of adaptive-landscape farming systems requires the use of spatially distributed mathematical models of soil erosion, which make it possible to estimate soil erosion losses on a given slope surface element, taking into account the spatial differentiation of all the main natural and economic factors of slope erosion-accumulative process.

The existing spatially distributed mathematical models of water soil erosion are primarily represented by physically sound dynamic models. The system of differential equations in partial derivatives of the balance of matter (water and sediments) and energy is a basis of these models. However, their high requirements for information support and excessive sensitivity to the accuracy of the input data limit possibility of their usage predominantly by research projects. The practice of conservation farming in different countries is still mainly based on the use of empirical mathematical models of soil erosion, such as the Universal Soil Loss Equation (USLE/RUSLE) (Wischmeier and Smith, 1978; Renard et al., 1997, etc.).

In Ukraine, for design of soil protection from erosion the mathematical models of soil losses developed by Shvebs (1974, 1981), Lavrovsky et al. (Lavrovsky et al., 1987), and Sribny (Sribny, 1977; Sribny, Vergunov, 1993), also belonging to the category of empirical mathematical models, are used or are recommended for use. All these models, including the Universal Soil Loss Equation, were originally developed to calculate the average annual soil loss on average for the slope, that is, they were models with lumped parameters that did not take into account the spatial variability of factors of modeled process. At a certain stage, the developers of the Universal Soil Loss Equation proposed a method for approximate accounting for changes in the factors of the erosion process along the length of the slope, but only within its convex part (Foster, Wishmeier, 1974). However, even this model is not properly calibrated and is not tested in the natural and economic conditions of Ukraine.

In recent decades, a spatially distributed physical-statistical model of soil erosion-sedimentation has developed in the Odessa National I. I. Mechnikov University (Svetlitchnyi, 1995, 1999; Svetlitchnyi et al., 2004; Pyatkova, 2011, 2013; Svetlitchnyi and Piatkova, 2019). Currently, this mathematical model is software implemented using the operators of the Software for Environmental Modeling (GIS-package) PCRaster (PCRaster …, 2018) and the programming language Basic. The model was successfully verified using observational data at runoff plots and experimental catchments of the Moldavian and Veliko-Anadol Water Balance Stations and the Boguslav Field Research Hydrological Base of the Ukrainian Hydrometeorological Institute (UkrHMI) (Svetlitchnyi, 1995, Piatkova, 2011; Svetlitchnyi and Piatkova, 2019), as well as of the results of field studies of water erosion using the radio-cesium method and the method of magnetic tracers (Zhidkin et al., 2015). The adequacy of modeling the spatial distribution of erosion-sedimentation by this model was also confirmed by comparison with the simulation results using the spatially distributed physically based dynamic model LISEM (Svetlitchnyi, Pyatkova, 2017). Recent studies on long-term forecasting of climate change (Krakovska et al., 206; Krasovska et al., 2017), surface runoff (Gopchenko et al., 2012; Ovcharuk. 2017) and hydrometeorological conditions of soil erosion (Svetlitchnyi, 2018) make it possible to use this model not only for a spatially distributed assessment, but also for a forecast of soil erosion within the plain part of Ukraine until 2100.

The purpose of this study is the spatially distributed quantitative assessment and forecast of erosion losses of soil and the development on this basis of recommendations to optimize the use of agricultural land on the example of the Pidhayetskyi district of the Ternopil region. The area is located within the Western region of Ukraine with a fairly high intensity of soil erosion where, in accordance with the long-term climate forecast, a further increase in erosion hazard is expected, at least during the warm season (Svetlitchnyi, 2018).

Water erosion losses of soils on the agricultural lands of the Pidhayetskyi region is the object of the study. Spatially distributed retrospective assessment of erosion losses of soil for the baseline period (1961–1990), their forecast until 2100 and the development of recommendations for optimization the use of erosion-hazardous lands of the region is a subject of the study.

Material and methods of research.

Pidhayetskyi district is located in the western part of the Ternopil region on the border of the Western Podillya and the Eastern Opilia on the Volyn-Podilsk

Upland. The territory of the district is 49638 ha (496.38 km^2) (Pidgajec'ka…, 2018).

The relief of the territory is wavy, crossed by river valleys of mainly meridian strike and beams, in the western part of it is hilly. The absolute heights of the divides are 380–410 m, and of the bottoms of river valleys (the Zolotaya Lipa, Koropets, Strypa rivers) are 240–330 m. The maximal height of the earth's surface within the district is 414 m. The distribution of the Pidhayetskyi district agricultural land in the range of slope gradients is shown in the Table 1.

Table 1. Distribution of the Pidhayetskyi district agricultural land in the range of slope gradients

Slope gradients, degrees	Area	
	ha	%
<1	7356.5	20.7
1–3	11724.5	33.0
3–5	7741.3	21.8
5–7	4157.0	11.7
>7	4538.5	12.8
Total	35517.8	100.0

The climate of the district is temperate continental and is characterized by mild winters, warm summers, and a significant amount of rainfall. The area is located at the boundary of two climatic zones: of the Western European zone in the west with a humid and moderately warm climate and East-Continental zone in the East with a continental climate (Geografija …, 2017). The average annual air temperature according to Berezhany meteorological station, which is located 25 km northwest from the administrative center of the district, is 7.2 °C, the average annual rainfall amount according to Berezhany meteorological station is 690 mm, according to the precipitation measuring post Pidhaitsi – 704 mm. (Klimatychnyj…, 2006). Most precipitation falls in the warm part of the year (April-October). The maximal rainfall in a single rain at Berezhany weather station was observed in August and reached 90 mm. The period 1961–1990 was characterized by a persistent winter with average monthly temperatures of –2.1 … –4.9 °C, with an average duration of snow cover of 84 days and an average maximal height of 37 cm in the end of winter (Klimatychnyj…, 2006).

The soil cover in the eastern part of the district (in the Podillya) is represented by podzolized chernozems and dark gray podzolized coarse-dusty medium loamy soils and in the western part (at Opilia) by gray and light gray podzolized loamy soils. Podzolized chernozems in comparison with dark gray podzolized soils are deeper, more humus-rich (2.5–3.5 %). Gray and light gray podzolized soils of Opilia in the upper horizons have a humus content of 1.8–2.2 %. The natural fertility of these soils is much less than that of the chernozems (Geography…, 2017).

Among 49638.00 hectares of land under the control of Pidhayetskyi district, agricultural land occupies 35517.79 or 71.6 % of the total area, including arable land – 29047.53 hectares (81.8 %), pastures –4702.49 ha (13.2 %), hayfields – 1376.47 ha (3.9 %), perennial plantings – 391.29 ha (1.1 %). In addition, 451.49 hectares (1.3 %) are under farm buildings and yards, forests cover 9365 hectares (18.9 % of the area), reservoirs – 592 hectares (1.2 %), swamps – 212 hectares (0.4 %) (Pidgajec'ka…, 2019).

The structure of sown areas of the district is presented in the Table. 2. The largest share in the structure of sown areas is occupied by cereal crops, which account for 50.8 % of the arable land, including 23.6 % of spring crops and 27.2 % of winter crops. The group of high-stem tilled crops (corn, sorghum, sunflower), whose soil-protective efficiency is very low, occupies 29.7 % of the arable land area. Perennial grasses with high soil-protective efficiency occupy only 3.5 % of the sown area.

Table 2. Structure of sown areas of the Pidhayetskyi district (Pidgajec'ka…, 2019)

No	Crops	Area, ha	Share in the structure of sown areas,%
1	High-stem tilled crops (corn, sorghum, sunflower)	8640.6	29.7
2	Low-stem tilled crops (soybeans, buckwheat, peas, potatoes, vegetables, watermelons and melons)	4264.1	14.7
3	Spring cereals	6841.0	23.6
4	Winter cereals	7887.1	27.2
5	Annual grasses	388.1	1.3
6	Perennial grasses	1026.6	3.5
	Total	29047.5	100.0

A quantitative assessment of soil erosion losses on agricultural lands of the Pidhayetskyi district of the Ternopil region was performed using a spatially distributed version of the physical-statistical model of soil erosion-sedimentation (Svetlitchnyi, 1995, 1999; Piatkova, 2008,2011; Svetlitchny & Piatkova, 2019). The years 1961–1990 were chosen as the baseline period due to the availability for this period of a complete set of information necessary for the model. The forecast was made for the middle of the current century (2031–2050) and its end (2081–2100) in accordance with the periods of the long-term climate forecast developed at UkrHMI (Krasovska et al., 2016; Krasovska et al., 2017).

The digital geodatabase for the territory of Pidhayetskyi district has been created using a topographic map of 1:100 000 scale, a soil map of 1:200 000 scale (Karta gruntiv…, 1967) and high-resolution satellite image from the GoogleEarth Internet service. Statistical materials from the website of the Pidhayetska State Administration, monographic literature and publications in the periodical scientific editions were used as a source of attributive information characterizing the use of land in the region. The values of climatic indicators for the baseline period were taken from the Climatic Cadaster of Ukraine (Klimatychnyj…, 2000), for forecast periods – taken in accordance with the climate forecast made in the Ukrainian Hydrometeorological Institute (Krakovska et al., 2016; Krakowska et al., 2017).

Comparative-geographical, cartographic, statistical and geoinformation modeling methods were used to achieve the purpose. The PCRaster environmental modeling package developed in the Department of Physical Geography of the University of Utrecht, the Netherlands (PCRaster …, 2018) was used as the basic GIS software.

Results and Discussion.

Creating the digital geodatabase. The digital database of spatially distributed data (geodatabase) includes sets of basic and derived digital maps of the district area. Digital raster maps created on the basis of digitizing of paper maps or a satellite image we will consider as basic maps. Digital raster maps created on the basis of basic digital maps using GIS software tools we will consider as derived maps.

The hydrologically correct digital elevation model, digital maps of soils and land use are the basic digital data layers that provide a mid-scale assessment of erosion soil losses within an administrative district based on the physical-statistical model of ONU. Screen copies of these three basic digital maps for the territory of the Pidhayetskyi district of the Ternopil region are presented in the Figures 1–3.

All basic maps are built in the WGS-84 UTM coordinate system with the same spatial resolution. The raster cell size is 50 m for all maps. When constructing a digital elevation model on a topographic map of 1: 100 000 scale all the main and additional relief contour lines were digitized, as well as the structural elevation lines (divides and talwegs). Spatial interpolation of point data was performed using methods of ordinary point kriging and radial basis functions, which gave similar results.

The set of derived maps includes a large number of digital raster maps, most of which are created in batch mode using capabilities of the Basic and PCRaster packages. Digital raster maps of slope gradients, expositions, streamlines, relative erodibility and partial characteristic of relative erodibility of soils, horizontal gradients of soil cover characteristics, in particular, are derivative maps are creating the process of implementation of the erosion-sedimentation model.

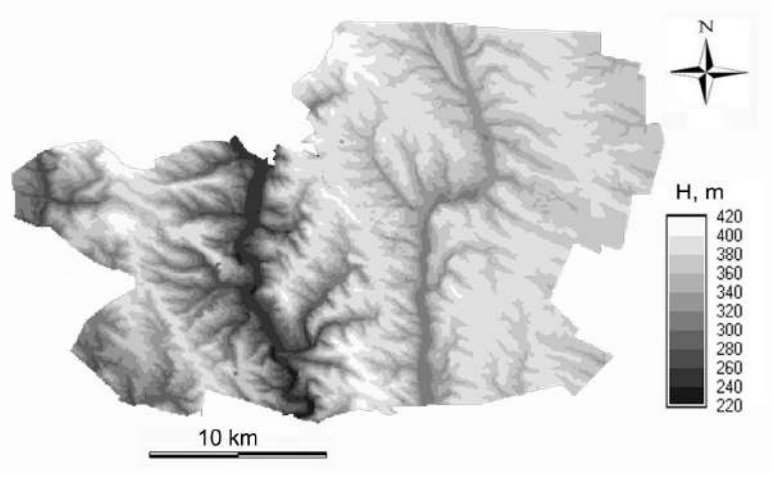

Fig. 1. Screen copy of digital elevation map of the Pidhayetskyi district

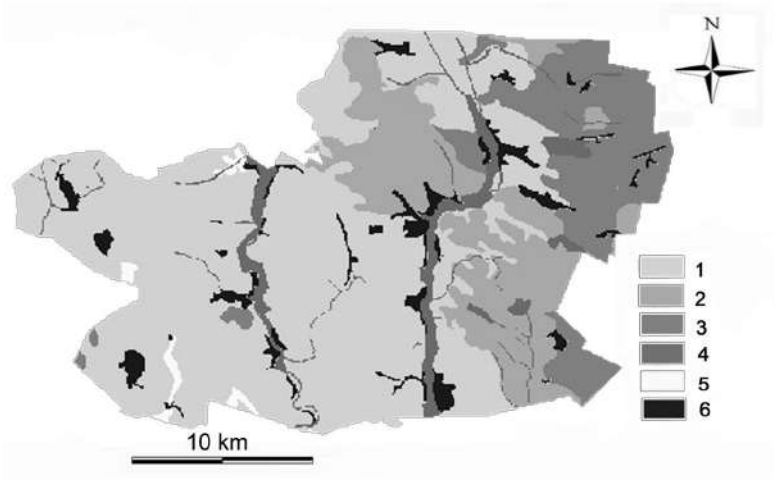

Fig. 2. Screen copy of soil map of the Pidgayetskyi district: 1 – light-gray and gray podzolized soils; 2 – dark-gray podzolized soils; 3 – podzolized chernozems; 4 – meadow-chernozem, chernozem-meadow, meadow, meadow-bog and other alluvial soils; 5 – exits of rocks; 6 – settlements

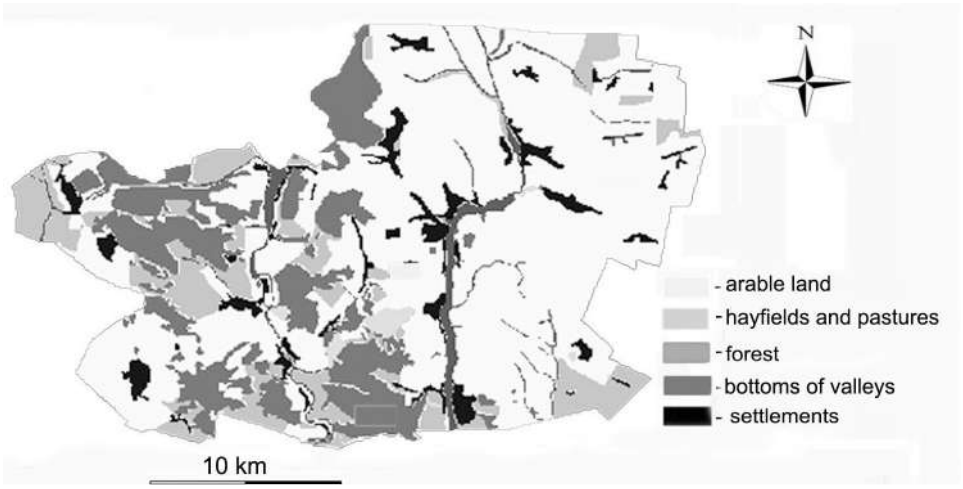

Fig. 3. Screen copy of land use map of the Pidhayetskyi district

Parameterization of the model. The hydrometeorological factor of rainstorm soil losses (K_{HM}) and the hydrometeorological factor of soil losses by the meltwater (K_{HMS}) are the main parameters of the used model of soil erosion, requiring geographical reference. The long-term average the K_{HM} values for the baseline climate period and for the forecast periods are determined by the previously established dependence of the K_{HM} on the long-term average sum of precipitation for May-September (Svetlitchnyi, 2018). The long-term average value of the hydrometeorological factor of rainstorm losses of soil for the baseline period, obtained using this dependence and the data from the precipitation measuring station Pidhaitsi (Klimatychnyj…, 2006), is 0.0052. The long-term average values of the K_{HM} for 2031–2050 and 2081–2100 in accordance with the forecast of monthly precipitation (Krakowska et al., 2017) (Table 3) are 0.0071 and 0.0063, respectively. Due to the fact that the forecast of changes in the average monthly precipitation for 2031–2050 and 2081–2100 is given in relation to 1991–2010, it became necessary to assess the change in the average monthly precipitation of 1991–2010 in relation to the baseline period (1961–1990). This assessment was performed using observational data from the reference weather stations of the region.

Table 3. Long-term average precipitation for May-September for the Pidhaitsi precipitation measuring post for the baseline period in accordance with the Climatic Cadaster of Ukraine (Klimatychnyj…, 2000) and for forecast periods for Western Region of Ukraine in accordance with (Krakowska et al., 2017)

	May	June	July	August	September	Sum
Average long-term precipitation for 1961–1990, mm	71	98	98	72	62	406
Change in precipitation 1991–2010 in relation to 1961–1990,%	-7	-12	4	10	35	
Average long-term precipitation for 1991–2010 years, mm	66	86	102	79	84	420
2031–2050						
Projected precipitation changes relative to 1991–2010 years,%	16	12	13	4	18	
Average long-term precipitation for 2031–2050 years, mm	77	96	115	82	99	469411
2081–2100						
Projected precipitation changes relative to 1991–2010 years,%	7	4	13	-3	10	
Average long-term precipitation for 2081–2100, mm	71	89	115	77	92	444

The long-term average value of the hydrometeorological factor of spring snowmelt erosion (K_{HMS}) for the baseline period in accordance with (Svetlitchnyi et al., 2004) equals to 0.0010. The K_{HMS} values for the forecast periods (2031–2050 and 2081–2100) in accordance with the forecast of spring surface runoff values (Gopchenko et al., 2012; Ovcharuk, 2017) are either close to zero (in the middle of the century) or equal to zero (in end of the century). That is, the erosion hazard of the district's agricultural lands in the prospect under consideration will be determined only by rainstorm erosion during a warm season.

The values of other parameters of the model are taken in accordance with the existing recommendations (Shvebs, 1981; Svetlitchnyi et al., 2004; Lisetsky et al., 2012).

Results of calculation and forecast of soil erosion losses. The result of the calculation of soil erosion losses within the Podhayetskyi district for hydrometeorological and land use conditions of the baseline period (1961–1990) are presented in the Fig. 4. The result of the calculation of soil erosion losses within the most erosion-prone arable land are presented in the Table 4.

The analysis in the Fig. 4 and the Table 4 allows us to state a generally high rate of erosion degradation of soils of arable lands of the district. Within hayfields and pastures, which make up the second main component of the farmland of the district, soil erosion losses are usually insignificant. This circumstance allows us to focus on the analysis of soil erosion losses precisely on arable land, occupying 81.8 % of the farmland and 58.5 % of the total district's area. The calculated average module of erosion losses of soils within the arable land of the district for the baseline period is 16.0 t/ha per year (Table 4). Most of the soil erosion losses, namely 13.6 t/ha/year or 85 %, are formed by rainfall in warm season, 2.5 t/ha/year (15 %) – by melt water in spring. The area of arable land with annual soil losses not exceeding 5 t/ha/year is 14056 ha or 48.4 %. The area of arable land with erosion losses exceeding 20 t/ha/ year is about 6720 ha or 23.1 % of its area. Within 2407 ha (8.3 %) of arable land, the estimated soil loss exceeds 50 t/ha/year.

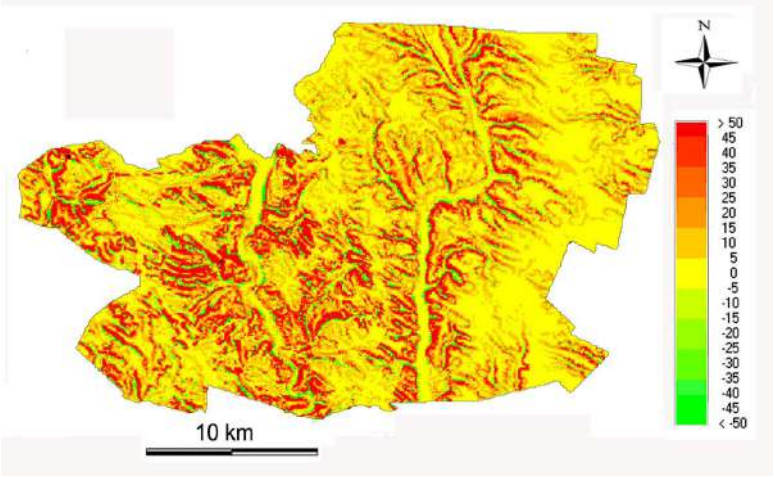

Fig. 4. The estimated average annual soil losses (t/ha/year) within the Pidhayetskyi district for the baseline period

Table 4. Average annual soil losses (t/ha/year) and distribution of the area of arable land of the district by gradations of erosion losses for the baseline period

Period, years	Season, year	<2		2–5		5–10		10–20		20–50		>50		Average annual soil losses, t/ha/year
		Area, ha	%	Area, ha	%	Area, ha	%	Area, ha	%	Area, ha	%	Area, ha	%	
1961–1990	Summer autumn	9960	34.3	4412	15.2	3935	13.6	4088	14.1	4246	14.6	2407	8.3	13.6
	Spring	17012	58.6	7555	23.0	3317	11.4	1019	3.5	145	0.5	0	0	2.5
	Year	8546	29.4	5510	19.0	3917	13.5	4356	15.0	4314	14.8	2407	8.3	16.0

In the middle of current century (2031–2050), in accordance with the predicted climate change (Table 3) while maintaining the structure of sown areas, the soil cultivation system, and the absence of special anti-erosion measures the erosion hazard of arable land in the district will increase, despite a decrease to insignificant values of erosion losses of soil in spring. The area of arable land with an average annual soil losses exceeding 20 t/ha will amount to 8153 ha (28.1 %), that is, it will increase by 1434 ha or 4.9 % compared to the baseline period. Accordingly, an area of land with erosion soil losses of less than 5 t/ha/year will decrease by 954 ha (up to 13102 ha or up to 45.1 %). At the end of the century (2081–2100), due to the projected decrease compared to 2031–2050 the amount of precipitation in the warm season, soil erosion losses on the arable lands of the district will slightly decrease (Table 5).

Table 5. Forecast of the average annual soil losses and distribution of the arable land area of the Pidhayetskyi district according to gradations of erosion soil losses (t/ha/year)

Period, years	Season, year	<2		2–5		5–10		10–20		20–50		>50		Average annual soil losses, t/ha/year
		Area, ha	%	Area, ha	%	Area, ha	%	Area, ha	%	Area, ha	%	Area, ha	%	
2031–2050	Summer-autumn	8423	29.0	4679	16.1	3656	12.6	4137	14.2	4869	16.8	3284	11.3	16.9
2081–2100	Summer-autumn	9392	32.3	4326	14.9	3771	13.0	4133	14.2	4646	16.0	2780	9.6	15.0

Discussion.

Based on the permissible erosion standards recommended by the National Standard of Ukraine (DSTU…, 2010), the arable land of the district with erosion losses of soil not exceeding 2 t/ha/year can be considered as erosion-safe. The estimated area of such lands in the district in 1961–1990 was about 8550 ha or 29.4 % of the arable land area. Another 5510 ha or 19.0 % of arable land with erosion losses of soil from 2 to 5 t/ha/year were characterized by low erosion risk. In total, these two categories of land occupied about 48 % of the arable land. They either do not require special anti-erosion measures, or allow to be limited by the simple soil-protective techniques, such as plowing transversely the slope, periodic deep plowing or plowing with soil deepening, as well as phyto-reclamation techniques (Svetlichnyi et al., 2004; Naukovi …, 2010; Zonalni…, 2010). However, almost 52 % of arable land is characterized by significant erosion risk. Within 8153 ha (28.1 %), the estimated soil loss exceeds 20 t/ha/year, and therefore the erosion hazard of these lands is characterized as very high or catastrophic (with soil losses of more than 50 t/ha/year) (Svitlychnyin and Chornyy, 2007; Tarariko et al., 2017, etc.). These lands require a set of special anti-erosion measures. Moreover, given the projected further increase in the erosion risk of arable land in the district, this requirement becomes even more urgent.

The calculations show that arable lands, on which the average annual soil loss exceeds 20 t/ha/year, cannot be protected from the progressive erosion degradation with their continued intensive use. They should be removed from the composition of the arable land. On lands with an average annual soil loss of 5–20 t/ha and moderate or high erosion hazard, it is necessary to implement the system of soil protection measures, the intensity of which is proportional to the degree of soil erosion hazard. Landscape-adaptive soil-protective farming system is by far the best option of such system. At the same time, it is necessary to emphasize the need to change the structure of sown areas here with a decrease of the share of row crops and an increase of the share of grasses, especially perennial ones. In accordance with the recommendations of agrarian science for the Western Forest-Steppe of Ukraine, even for the first (least erosion-hazardous) ecological-technological group of lands, the optimal permissible limits for saturation of crop rotation with perennial grasses are 10–30 % (Tarariko, 1990). Currently, perennial grasses occupy only 3.5 % of the sown area of the district (Table 2).

Provided that 8150 hectares of the most erosion-hazardous lands will be removed from the arable land and the share of perennial grasses in the crop rotation will be increased to 15 % due to a corresponding decrease in the share of row crops, it is predicted that for 2031–2050 the average soil losses on arable land of the district will decrease to 3.4 t/ha/year. At the same time, lands with no or weak erosion hazard, that is, with soil losses not exceeding 5 t/ha per a year, will occupy about 65 % of the arable land.

When 8150 ha will be removed from the arable land, the share of arable land in the composition of agricultural land of the district will decrease from 81.8 % to 58.8 %. Based on a generalization of the results of studies conducted in Ukraine, Makhortov (1999) recommends the optimal share of arable land in the composition of agricultural land from the range of 45–55 % for the Forest-Steppe zone. According to the research of Carik (2010) in an optimal model of the land use structure as a whole for Podillja, arable land as part of agricultural land should occupy 60 % of their area, and directly for Pidhayetskyi district – 58.7 %. Thus, withdrawal from intensive agricultural use of lands for which the erosion losses of soil projected for 2031–2050 exceed 20 t/ha/year (Table 4), will make it possible to bring the structure of arable land to the optimum.

The erosion-hazardous lands removed from the arable land are recommended for use under hayfields, pastures or permanent afforestation with the mandatory implementation of a range of anti-erosion measures, including, if necessary, hydro reclamation measures.

Conclusions.

1. Most of the arable land of the Pidhayetskyi district of the Ternopil region is erosion hazardous. Under the existing structure of crop area, the estimated average annual soil losses for hydrometeorological conditions of 1961–1990 is 16.0 t/ha per a year, and land with a very high erosion hazard with annual soil losses exceeding 20 t/ha per a year occupy 23 % of the arable land.

2. Due to the projected increase in precipitation during the warm season in the middle and the end of the current century, further intensification of soil erosion is expected, especially expressed in 2031–2050, when the average annual soil losses within arable land in the district will increase to 16.9 t/ha/year, and the area of land with a very high erosion hazard will increased up to 28 %.

3. Ensuring the protection of arable land of the district from erosion destruction is impossible without withdraw from the arable land about 8.15 thousand hectares of the most erosion-hazardous land. This will reduce the share of arable land to 58.8 % of the agricultural land, which will bring it as close as possible to the optimum and will allow to reduce soil losses due to erosion to permissible values using soil-protective landscape-adaptive farming systems.

4. In solving the problem of protecting the arable lands of the district from erosion degradation, the increase in the area of perennial grasses from 3.5 % to 15 % plays an important role.

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Volcanic and fault-fractured ore-controlling structures and minerals of the Azerbaijan part of the Lesser Caucasus

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Abstract. This article is focused on volcanic and fault-fissure ore-controlling structures of the Lesser Caucasus. The territory of the Lesser Caucasus is dissected by many deep tectonic faults, along which volatile compounds of postmagmatic products and water vapor migrate from great depths. The presence of numerous tectonic deep faults, which provide hydrodynamic connection of waters of fracturse, and fracture-veins, determines the complex mineralization of the chemical and gas composition of mineral-thermal waters throughout the studied area. The study of volcano-intrusive and fault-fracture ore-controlling structures, volcanogenic formations, petrochemical composition of rocks and associated mineral deposits and mineral-thermal waters of the Azerbaijan part of the Lesser Caucasus is relevant from a scientific and practical points of view. A detailed study of the modern structure of the Lesser Caucasus shows that transverse rupture faults and deep flexures cut through the folded system. Deposits of various minerals, including mineral and thermal waters, are confined to these ruptured faults. The study revealed that the formation and discharge of numerous outcrops of carbonic mineral and thermal waters occurs mainly in fissure systems, in deep tectonic faults. In the Lok-Karabakh zone, most of the sources of the formation of gold-bearing placers belong to the deposits and manifestations of the gold-quartz-low-sulphide formation. Gosha, Kedabek, Karadag, Chovdar, Dagkesemen, Gyzylbulag and less significant deposits and ore occurrences are located in this zone. The Dashkesan ore region is distinguished by the reserves of iron, alunite and cobalt. The Zaylik alunite deposits are world famous in terms of large reserves. Analysis of geological materials confirms that the origin and distribution of deep tectonic faults plays a major role in the formation of geological, including volcanoplutonic, metamorphic processes and associated ore formation. Currently, there are dozens of variously evaluated and explored gold deposits on the territory of the Republic. The bulk of the primary deposits are located in the Lesser Caucasus part of the Republic.

Keywords: volcanism, minerals, gold deposits, mineral and thermal waters.

Вулканічні і розломно-тріщинні рудоконтролюючі структури і корисні копалини Азербайджанської частини Малого Кавказу

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Анотація. Дана стаття присвячена вулканічним і розломно-тріщиним рудоконтролюючим структурам Малого Кавказу. Територія Малого Кавказу розсічена безліччю глибинних тектонічних розломів, по яких мігрують леткі сполуки постмагматичних продуктів і водяні пари, що надходять з великих глибин. Наявність численних тектонічних глибинних розломів, по яких відбувається гідродинамічний зв'язок тріщинних, тріщинно-жильних вод, зумовлює строкату мінералізацію хімічного і газового складу мінерально-термальних вод по всій досліджуваній площі. Вивчення вулкана-інтрузивних і розломно-тріщинних рудоконтролюючих структур, вулканогенних формацій, петрохимичного складу порід і пов'язаних з ними родовищ корисних копалин, мінерально-термальних вод Азербайджанської частини Малого Кавказу є актуальним з наукової та практичної точки зору. Детальне вивчення сучасної структури Малого Кавказу показує, що поперечні розривні порушення та флексури глибокого закладення розтинають складчасту систему. До цих розривних порушень приурочені родовища різних корисних копалин, в тому числі мінерально-термальних вод. З'ясовано, що формування і розвантаження численних виходів вуглекислих мінеральних і термальних вод відбувається переважно в тріщинних системах, в глибоких тектонічних розломах. В Лок-Карабаській зоні велика частина джерел формування золотоносних розсипів належить до родовищ і проявів золото-кварцово-малосульфідної формації. У цій зоні розміщені Гошінське, Кедабекське, Карадазьке, Човдарській, Дагкесеменське, Гизилбулагське і менш значущі родовища і рудопрояви. Дашкесенській рудний район виділяється за запасами заліза, алуниту і кобальту. Всесвітньо відоме за величиною запасів Зайлікське родовище алунітів. Аналіз геологічних матеріалів підтверджує, що походження і закономірність поширення глибинних тектонічних розломів відіграє основну роль у формуванні геологічних, в тому числі вулканоплутонічних, метаморфічних процесів і пов'язаного з ним рудоутворення. В даний час на території республіки нараховуються десятки різного ступеня оцінених і розвіданих золоторудних родовищ. Основна кількість корінних родовищ розміщені в Малокавказькій частини республіки.

Ключові слова: вулканізм, корисні копалини, золоторудні родовища мінеральні і термальні води.

Introduction.

The Azerbaijanian part of the Lesser Caucasus is a complex system of mountain ranges and volcanic uplands, different from the Major Caucasus by lower absolute altitudes and insignificant manifestation of contemporary glaciation. The area of the Lesser Caucasus is mostly tectonic-denudation terrain with dense erosion and deep fracturing.

The Lesser Caucasus is characterized by the development of volcanogenic formations (from Upper Paleozoic to Quaternary periods), bent in the gently sloping folds of latitudinal in the West and Caucasian in the South-East strike. There are distinct tectonic zones composed of carbonate and volcanogenic rocks of Cretaceous period and tufagenic-volcanogenic rocks of Paleocene and Eocene age, accumulated in the latitudinal riftogenic depressions (Abdullaev, et al., 1991; Mustafaev, et al., 2011).

Within the Lesser Caucasus, the Lok-Karabakh, Geicha-Akera, Miskhan-Kafan structural-formation zones are designated (Geologiya Azerbajdzhana, 2005). The Talysh structural-formation zone is confined to the northeast border of the Lesser Caucasus-Elburz folded system and is an isolated horst that submerges under the Neogene-Quaternary deposits of the Lower Araz depression in the northwest and the Quaternary deposits of the Kura fault in the northeast (Geologiya Azerbajdzhana, 2001).

By age, the Mezozoic magmatic formations of the Lesser Caucasus are identified to the Middle-Jurassic, Upper Jurassic-Lower Cretaceous, Lower Cretaceous and Upper Cretaceous periods.

Broadly distributed deposits in the Lesser Caucasus are of the Paleozoic Era, the oldest being those of the Emsian stage of the Lower Devonian period. Those are metamorphic slates, silicified limestones, dolomites, quartzites, sandstones, argillites and clayey slates. The thickness of the deposits is over 1,200 m. The Jurassic deposits in the area comprise highland and middle-mountainous zones. The Lower Jurarassic is represented by clayey and clayey-sandy slates, aleurites, sandstones. The Middle and Upper Jurassic epochs are manifested by volcanic, volcanogenic-sedimentary and sedimentary facies of over 3,000 m thickness.

Materials and methods.

The article uses the results of field and laboratory surveys performed by the authors. We also used published and fund materials of various authors working in the Republic. We performed typing of the ore and hydro-mineral resources of the studied area and characterized their chemical composition and medical properties of mineralized waters.

Discussion.

The Lok-Karabakh zone within the Republic is located on the eastern slope of the Lesser Caucasus and is characterized by richness and diversity of ore and hydromineral resources. Especially notable are the waterways of the territory, represented by the Aghstafa, Hasansu, Tovuzchay, Dzegamchay, Chagirchay, Shamkirchay, Ganjachay Rivers.

In the basins of those rivers, gold-bearing placers have been discovered. Most of the sources of development of gold-bearing placers belong to the deposits and manifestations of gold-quartz-low-sulfide formation and are represented by steeply dipping veins of chiefly quartzitic composition and also zones of hydrothermally altered rocks mostly belonging to the facies of secondary quartzitic metasomatites.

Given that all other conditions are equal, the possibility of existence of a placer depends on the proportion between individual links of denudational morphosystems promoting the formation of placer (Fig. 1).

Based on paleogeographic analysis, the conclusion is that in the epoch of formation of gold-bearing alluvial layers embedded in the basis of the section, the climate was continental, and the physical weathering that mostly forms large-fragment alluvium dominated. The Lesser Caucasus is also rich in various genetic types of gold ore deposits such as Soyutlu, Gizil Bulag (Kalbajar District), Vejnali (Zangilan District), Gosha, (Tovuz District), Kedabek (Kedabek District), Dagkesaman (Qazakh District), Piyasbashi (Ordubad District) (Babazade, 2003).

The Shamkir Upland, where the Gosha gold-pyrite deposits are located, is a large structure of sub-latitudinal strike. Its structure is composed of mostly Middle Jurassic volcanogenic formations, torn by Upper Bajocian granitoid intrusive complexes.

The Gosha gold-pyrite deposits are typical representatives of volcanogenic deposits with progressive ore-formation and are connected with the continuous basalt-andesite-rhyolite formation, localizing in the vault part of the sub-volcanic structure. The deposits are characterized by the confinement to the local regional-dome structure of the Jurassic age, where the central place belongs to the volcanic-tectonic structure held by the intersection of large regional faults of northwest, sub-meridian and sub-latitudinal strikes (Mansurov, et al., 2018).

Besides the Gosha deposits, within the Lok-Karabakh zone, there are Kedabek, Chovdar, Dagkesemen, Gyzylbulag and less significant deposits, where ore has been developed as a result of the activity

of magmatic systems which had occurred in the Middle-Late Mezozoic Era.

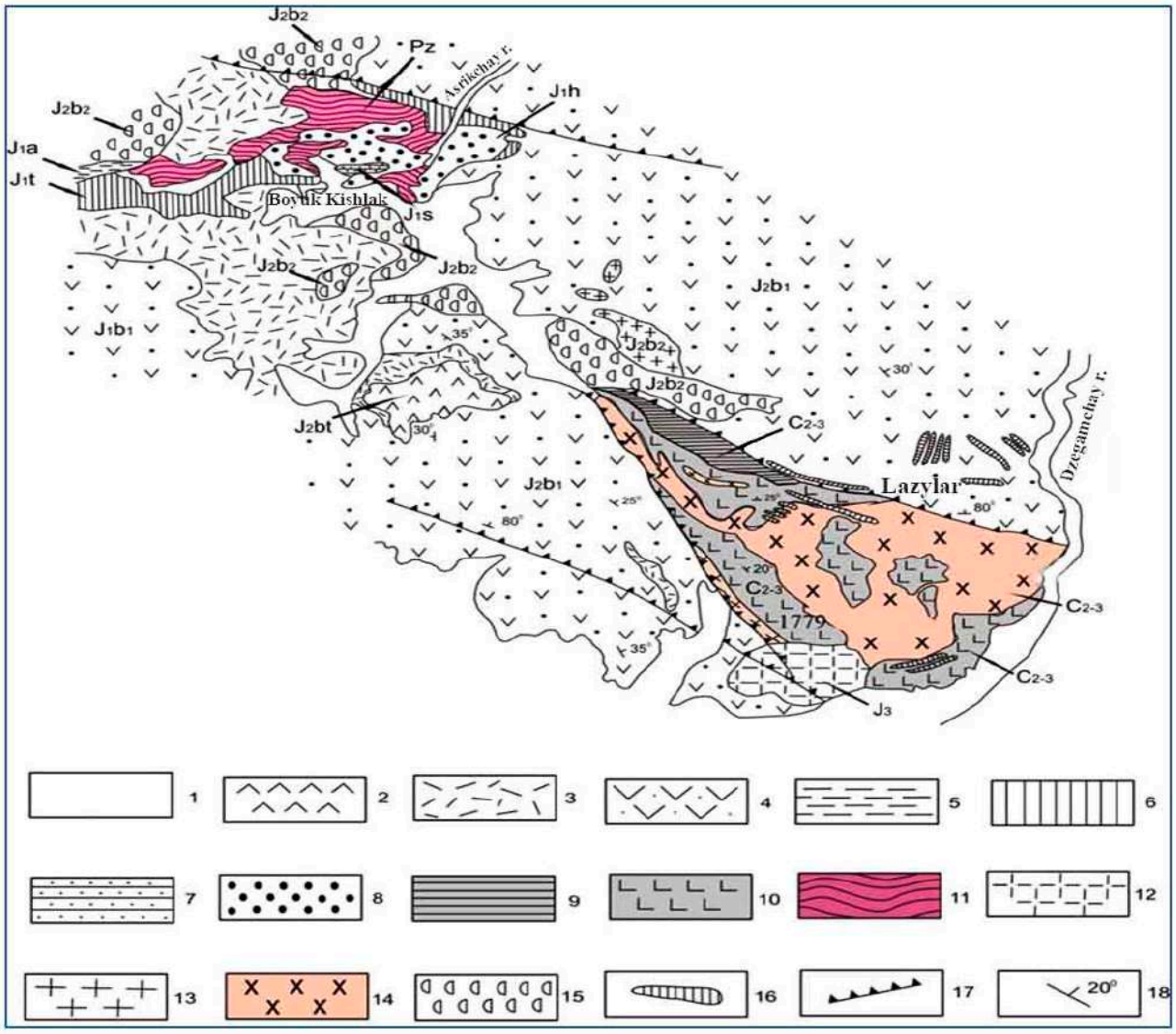


Fig. 1. Schematic geological map of the interfluves between the Dzegamchay and Asrikchay

1-contemporary and Upper Quaternary deposits, alluvial and alluvial-prolluvial: loams, loamy sand, pebble stones, boulders; 2- Bathonian stage: plagioclase and pyroxene porphyrites, lava breccias, volcanic breccias and tuffites; 3-Upper Bajocian sub-stage: agglomerate lava flows, tufa, tuffites, tufa-breccias of rhyolite and rhyolite-dacites with interlayers of tufa sandstones, tufa gravelites and tufa; 4-Lower Bajocian sub-stage: agglomerate lavas, lava breccias, tufa conglomerates, tufa breccias, diabase flows, rarer andesites, which transform into patches of tufogenic sandstones, aleurites, tufa and tufa gravelites; 5- Aalenian stage: sandy-clayey slates and tufa sandstones; 6- Toarcian stage: clayey slates, slatelike and thin platy aleurites that contain concretions of ash tufa and tufa-aleurites; 7-Sinemurian stage: sandstones with tufa inclusions and interlayers of limestones; 8-Hettangian stage: basal conglomerates with layers of quartzitic sandstones, rarer clayey slates; 9-Middle and Upper Carbon: tuff-sedimentary layer: alternation of tuffites, tufa aleurites, aleurites, clayey slates and sandstones; 10-Middle and Upper Carbon: volcanic layer, alternation of different-sized fragmented tuff of intermediate – basic composition with thin interlayers of aleurites and clayey slates; 11- Eopaleozoic: micaceous-chlorite, sericite clayey, siliceous, quartzitic, clayey-graphite slates; **Intrusive formations:** 12-Upper Jurassic granitoides and quartzitic diorites; 13-Upper Bajocian plagiogranites; 14-Upper Paleozoic stratum injections of syenite-diorites. **Subvolcanic and vein formations:** 15-Upper Bajocian rhyolites, rhyolite-dacites; 16-dikes of diabases and andesites; 17-regional faults; 18-elements of embedding of the rocks.

The Dashkesan ore district is notable for reserves of iron, alunite and cobalt. The Dashkesan iron ore deposits have provided iron concentrate to the Rustavi Metallurgical Plant in Georgia for a long time.

Globally recognized as the one having greatest deposits of alunites, the Zeylik deposits of alunite provide raw material for obtaining aluminum in the aluminum industry, as well as obtaining sulfuric acid and

fertilizers. Aluminum ore may be annually processed to 200 thou tones of agloporite (sintered fly ash), a light concrete.

The Dagkesaman gold ore deposits are confined to the Kazakh depression of the Lok-Karabakh structural-formation zone of the Lesser Caucasus. The geological structure is composed of a complex of sedimentary-pyroclastic effusive and subvolcanic rocks of the Cretaceous and Paleogene-Neogene periods. The main folded structure of the deposits is an anticline fold of the same name, belonging to the northeast strike. In the pre-axis part of the fold, there are outcrops of the albitophyre and rhyodacite bodies and the ramifications of the Agdam-Rivazlin fault which were the canals for the inflow of the ore-bearing hydrothermal fluids and sedimentation of the ores in the newly-formed mineralized zones, the number of which is more than ten, including the three main zones.

Within the volcanogenic upland, clearly manifested the Gosha gold-pyrite deposits are some of the most promising objects of the Kedabek mining district. The ore bodies are of the vein-impregnation type.

Complex geological-structural conditions of the region, in which there are signs of recent powerful volcanic processes, have led to a vast amount (over 50 mineral sources) of mineral waters with various conditions of the circulation. Formation and discharge of numerous seeps of carbon dioxide mineral and thermal waters mostly take place in fractured systems, in deep tectonic faults (Mustafaev, et al., 2011).

The **Geicha-Akera** folded region is a synclinorium oriented northwest, which is in the central part of the Lesser Caucasus, where there are numerous derivatives of intrusive and effusive magmatism, especially the Quaternary lava complex that is significant in the formation of mineral and thermal waters. In this region, there have been studied over 300 sources united in four zones: İstisu-Kalbajar, Turshsu-Shırlan, Minkend-Ahmedli and Lok-Agdam (Geologiya Azerbajdzhana, 2005).

The İstisu-Kalbajar zone has a complex geological structure caused by greater diversity of the sedimentary, volcanogenic-sedimentary, volcanogenic and intrusive rocks. Tectonically, it is included in the Kalbajar basin fold that is one of the main elements of the central part of the meganticlinorium of the Lesser Caucasus. The geological section of the sediments, which is included in the Kalbajar synclinorium of the Lesser Caucasus, covers the Cretaceous – Anthropogenic interval with some breaks.

Cretaceous sediments in the upper reach of the basin of the Terter River have a relatively limited distribution. They are ruptured by numerous intrusive hyperbasites that make up the ophiolite belt of the Lesser Caucasus, represented by thick sedimentary, volcanogenic-sedimentary and volcanogenic rocks.

Paleogenic sediments with thickness of 1,500 m and more are mainly distributed within the Kalbajar-İstisu synclinorium belt, especially in its central part, in the sites of the Shurtan, İstisu, Zeylik, south of villages Chirag, Keshtek and others.

Neogene sediments are quite broadly distributed and represented by andesites, andesite-dasites and their pyroclastic sediments of up to 1,400 m thickness, chiefly on the left bank of the Terter River. This indicates that the centers of flows of the volcanoes of this period were located along the current valley of the Terter River.

A distinctive trait of the volcanites of the Later Miocene-Lower Pliocene age in the Lesser Caucasus is that they are mainly composed of the of the intermediate and acidic composition of pyroclastic and effusive formations. The volcanism is mainly represented by andesites, trakhyandesites, dasites, trakhydasites and rhyolites (Imamverdiev, 2000; Imamverdiev, et al., 2020).

In the İstisu area (Kalbajar district), numerous dikes of rhyolites and andesite-dasites are seen, indicating broad distribution of deep tectonic faults.

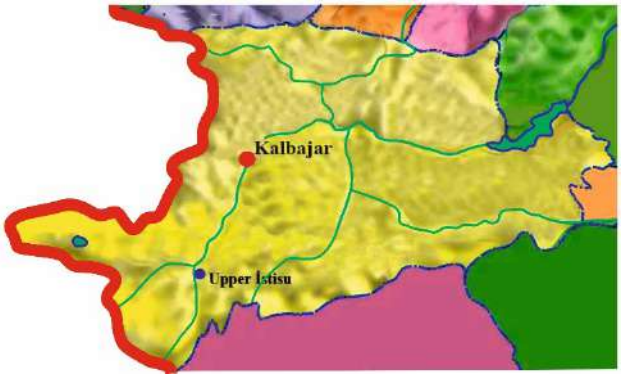
Within the Geicha-Akerin zone, there are gold-ore (Soyudlu – Zod, Agduzdag) and mercury deposits (Shorbulag, Aggaya, Levchay and others).

The discovery of the Zod-Soyudlu gold ore deposits (Kalbajar district of Azerbaijan and Basarkecher district of Armenia) was a powerful stimulus to carrying out specialized searches for gold in the Lesser Caucasus. These searches led to discovery of a number of deposits of gold and rich gold and silver-bearing ores (Baba-zade, 2003).

Note: From 1970–1980, a detailed survey of the Zod-Soyudlu deposits was conducted and the industrial reserves were assessed as 89 t of gold and 145 t of silver, and since 1976 they have been illegally exploited by the Republic of Armenia. Out of 23 ore veins, only 7 are located in the Basarkecher district (Armenia). This issue has its own history, and we consider that there is no need to describe it in detail in the scientific article.

In the upper reaches of the Terter River, it has long been known that there are numerous sources of carbon dioxide-containing mineral water with various temperatures (Table 1). They are mainly localized in shallow faults, which support the regional ones, and the thermal sources are usually confined to deep faults and faults of average depth. By the chemical composition and medicinal properties, these waters are identical to the globally famous sources Karlovy Vary in the Czech Republic, Germany, Zheleznovodsk in Russia.

Table 1. The main parameters of deposits of mineral waters of Kalbajar district of the Lesser Caucasus (Bank of the regional data)

№	The main parameters	Geological-hydrogeological data
1	Name of the deposits	Upper İstisu (Kalbajar district)
2	Types of minerals	Carbonaceous – CO_2- thermal waters
3	Geographical coordinates and locations of the deposits	In the Upper Reach of the Terterçay, at the distance of 20 km southwest of Kalbajar district  39°56`49``– C; 45°57`43` – B; Altitude – 2,200 m
4	Types, age and geologic-lithologic composition and other parameters of aquatic resources	The deposits are confined to volcanogenic layer of the Middle Jurarassic period. There are 6 wells of 365–700 m, exposed by thermal waters of the temperature of 70^{0}C, flow rate of 44–400 m^3/day, overall discharge (flow rate) – 3,200m^3/day. HCO3–50 %- equiv; Ca – 8 %- equiv; Na – 40 %- equiv; Cl – 34 %- equiv; M – 4.4–7.6 g/L

The **Turshsu-Shirlan zone** is located in Shirlan district in the border zone of the eastern part of the Lesser Caucasus. The main reason for discharge of the mineral water in the Turshsu-Shirlan zone is the thrust fault line of the Lesser Caucasus. Fragmentation and folds on the Mezozoic layers in the indicated region are represented by three ramifying thrust fault lines, one being along the border between the Middle Jurassic volcanogenic and Lower Cretaceous layers, the second one on the border of the Tithinian limestones, and the third on the ultra-basic rocks in which typical tectonic breccias had formed.

By the types of support and discharge, the Turshsu-Shirlan syncline belt of mineral water is specific because deposits with similar hydrogeologic conditions are quite rare. As a result of carbon dioxide and high hydrostatic pressure from the ultra-basic formation, the ascending springs discharge.

On the schemes of tectonic zoning of the Caucasus, available in various studies conducted over many decades, its southern part was distinguished as the Araz (Nakhchivan) block of the Central Iranian microcontinent or the **Araz Mega-Zone** that is included in the Anatolia-Caucasian-Iranian segment of the Mediterranean Folded Belt. The aspects of geology, tectonics and fossils of the Nakhchivan region are superbly described in the monograph "Geology of the Nakchchivan Autonomous Soviet Socialist Republic", where the scheme of tectonic zoning designates the Sharur-Julfa and Zengezur anticlinorium and the Ordubad synclinorium that divides them (Geologiya Azerbajdzhana, 2005; Pılchin and Eppelbaum, 2020).

The studies conducted in the Araz Mega Zone focusing on the proportion of the stages of the development of the region with folded structures allowed distinguishing three structural complexes that correspond to the three stages of the development of the region: 1 – Baikal – Pre Cambrian, Lower Paleozoic (along the Girratag fault); 2 – Hercynian – Middle-Upper Devonian, Carbon, Permian, Triassic age; 3 – Alpine – Jurassic and Lower Cretaceous, Upper Cretaceous, Paleogene – Eocene, Oligocene age (Rustamov, 2005).

In the Middle Devonian age, the territory underwent transgression. Here the Triassic rocks are more closely related to the Paleozoic age rather than the Jurassic period. At the border between the Triassic and Jurassic deposits, there occurs a significant change in the geological conditions. There are broadly distributed volcanic formations of 1,000–3,500 m thickness (Azizbekov, 1961; Karimli, 2020). The Paleogenic rocks are broadly distributed, especially in the Nakhchivan Autonomous Republic. They are represented by alternation of clays, sands and marlstones. In the upper

reaches of the Terter and Akara rivers, effusive rocks, tufagenic rocks, pyroclasts were observed. Along with the sedimentary deposits, the Nakhchivan Autonomous Republic has many volcanogenic formations with thickness of 1,000–3,500 and more.

The Miocene deposits in the Nakhchivan Autonomous Republic are represented by clays, marlstones, limestones, sandstones and halite, measuring up to 2,000 m thickness. The Nakhichivan Autonomous Republic in Azerbaijan Republic is located in the southwest part of the Lesser Caucasus and occupies the area of 5.5 thou km^2, its natural border of which is the Araz River in the south and southwest, and the Republic of Armenia – in the northeast and northwest.

The Talysh zone is comprised by Paleogenic and Neogene rocks. The Astara anticlinorium, Lerik synclinorium, Burovar upland, Yardimli and Jalilabad synclinoriums are distinguished (Mamedov, 1999; Kerimov, 2020).

The Paleogene rocks are represented by the volcanogenic-sedimentary layer composed of tufa sandstones, tufa aleurites, clays and sandstones, and 2,000–3,000 m thick basalt layers. The Neogene sediments are manifested by clays with layers of sandstones and limestones with thickness up to 1,500 m (Fig. 2). The following structures were distinguished – Astara anticlinorium, Lerik synclinorium, Burovar upland, Yardimli and Jalilabad synclinorium.

The Astara anticlinorium has the most complex structure and is located on the extension of the northeast wing of the Elburz folded belt. The anticlinorium is composed of tufa-sedimentary rocks of the Upper Cretaceous-Paleogene and volcanogenic rocks of the Lower and Middle Eocene. In the current erosional section, it represents two structure: the Astara Upland and Kosmolian Depression (Mamedov, 2000; Mamedov, et al., 2007).

The structure of the Lerik synclinorium includes the volcanogenic-sedimentary complex of the Upper Eocene. This synclinorium is a structure of the second row and is overlaid by the Yardimli synclinorium in the northwest, and is cut by the marginal Pre-Talysh fault in the southeast. The southwest border of the synclinorium is stretched in a straight line northeast due to the length-wise fault (Rustamov, 1995).

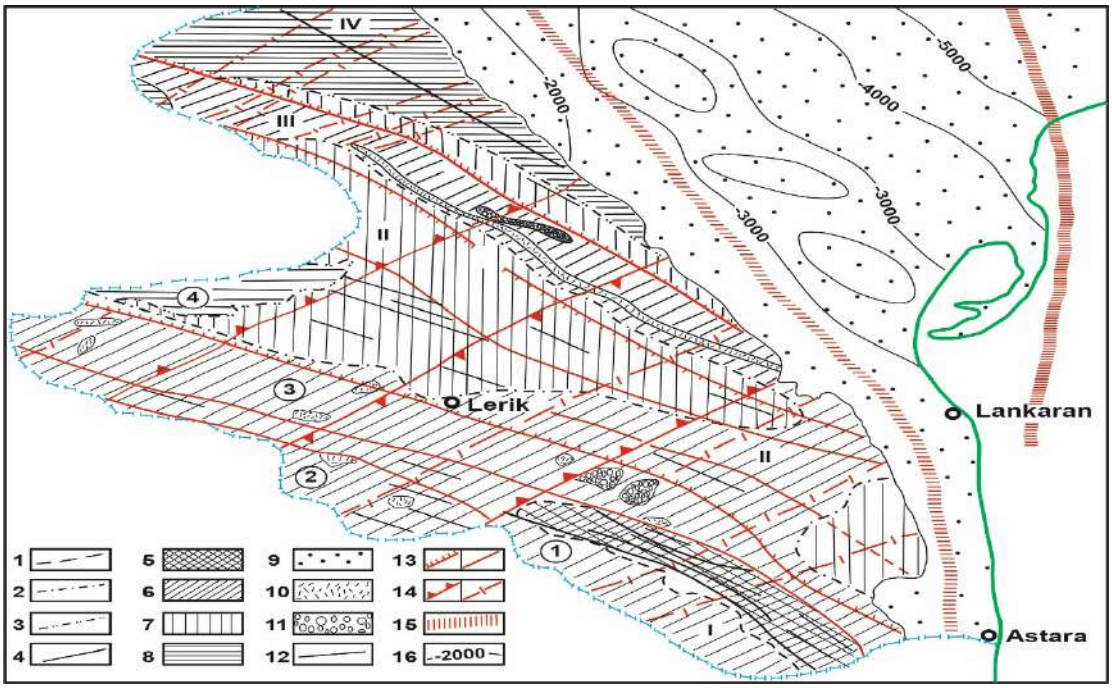


Fig. 2. Geological-tectonic map of the Talysh zone

1–4 – borders of the structural stages in the foot: 1 – Early Eocene; 2 – Early Oligocene; 3 – Middle Miocene; 4 – Pleistocene. 5–9 – formations and complexes: 5 – sedimentary-tufagenic of Upper Cretaceous-Paleogene age;6 – volcanogenic (alkaline basaltoids) Eocene; 7 – marine molasse Oligocene-Early Miocene; 8 – lagoon-marine Middle Eocene; 9 – continental-marine quarter. 10–11 – subvolcanic intrusions: 10 –Eocene; 11 – subalkaline ultrabasites; 12-axis of the fold; 13 – faults at the borders of the tectonic zones; 14 – transversal faults (flexures); 15 – buried deep faults according to the geophysical data; 16 – isolines along the buried surface of the Upper Cretaceous deposits.

The Alaşar-Burovar anticlinorium is developed only in the northern Talysh, located between the Bolgarchay and Veravulçay rivers. The eastern wing of the anticlinorium is separated from it by the Pre-Talysh deep fault and is completely covered by Quaternary deposits. The length-wise structures of the Talysh zone have transversal faults that affect the distribution of

sedimentary, volcanogenic and intrusive formations (Kazimova and Kazimov, 2020).

In general, the Talysh and Lankaran Lowland are characterized by mountain terrain that is rapidly descending northeast towards the Caspian Sea. Mineral waters in the eastern part of the region are identified to the chloride type, and are accompanied by hydrogen sulfide (H_2S) and methane (CH_4) in the north, whereas gas flows in the south are mostly composed of nitrogen (N_2). In the northwest part, the mineral waters contain hydrogen sulfide and sulfate and hydrocarbon. Such a distribution may be explained by geological-structural conditions in the area of discharge of groundwater, structural-facies relationship with the phases of volcanogenic activity, composition and facies of volcanites (Van der boon, etal., 2015; Tagiyev, et al.,2015).

Mineral-thermal waters are confined to the tectonic fractures and mostly flow from Peleogenic rocks, are represented by tufa sandstones mixed with tufa aleurolites and argillites, limestone-sandstones, limestone tufa aleurolites are covered that in some places by young analcime andesites or torn by gabbro-teschenite rocks. In the north, there is a group of highly mineralized (up to 17 g/l) hydrothermal sources of the Masalli. Their temperature reaches 64^0C, they contain chloride and sodium and calcium, are accompanied by methane and hydrogen sulfide, which is explained by their connection to the oil-bearing suites. In the central part of the region, there is a group of sources Lankaran, its waters have lower temperature and comparatively low mineralization (3 g/l). They are mainly accompanied by nitrogen and hydrogen sulfide gases. The south group of thermal (38–50^0C) sources is highly mineralized (20 g/l), followed by nitrogen of natural origin, determined by the proportion of argon and nitrogen (Tagiyev, 2001; Tagiyev, et al., 2019).

Mineral-thermal waters of all the mentioned groups are identified to chloride-sodium-calcium water, i. e. typical for oil-bearing regions, thus they need to be considered reliable criteria for the search of oil and gas in the regions adjoining this zone.

Currently, in Azerbaijan, there is active ongoing integrated work on restoration of the completely destroyed liberated areas of the Lesser Caucasus.

Taking into account the complexity of geologic-tectonic development of the Lesser Caucasus, predatory exploitation of dozens various fossil deposits by Armenia, the scientific and field geological surveys in the occupied regions have been practically stopped and there is a complex survey to be carried out by the geological and ecological survey of the Republic.

We have to note that over more than 30 years, the Armed Forces of Armenia have occupied not only the territory of Nagorno-Karabakh, but dozens of other districts of the so-called “buffer zone” around the Nagorno-Karabakh. Moreover, in the recent years, there have been great scientific achievements made in geology around the globe mostly due to the development of novel cosmogeological, geological, geophysical and geochemical studies.

We are glad to note that our armed forces have already liberated the occupied territories and this region is already being restored by the forces of our republic. Using modern methods, new deposits of ore, non-metallic minerals and mineral waters will be discovered in this rich region.

A detailed inventory of the stratigraphic division of the Jurassic deposits, a biostratigraphic scheme of the Upper Cretaceous deposits should be performed, taking into account the new and highly informative methods of identification of the recent tectonic activity, detecting the tension zones, compressions and horizontal shifts, as well as renewal of surveys of the ophiolite zone of the Lesser Caucasus.

Conclusions

1. The study and assessment of various types of gold-bearing deposits, especially in the volcanic belts of the Azerbaijan part of the Lesser Caucasus, are some of the most relevant issues of extending the mineral and raw material basis of copper, gold, rare, rare-earth elements and other deposits of fossil fuels.

2. Analysis of geological materials confirms that the origin and pattern of distribution of deep tectonic faults is important in the development of geological, including volcanic- plutonic, metamorphic processes and ore development that is related to them. Currently, in the territory of the Republic, dozens of assessed and explored gold-bearing deposits are known. The greatest amount of original deposits is located in the Lesser Caucasus part of the Republic.

3. The territory of the Lesser Caucasus is divided by numerous deep tectonic faults, where volatile compounds of post-magmatic products and water vapors from migrate great depths. The presence of numerous deep tectonic faults has been noticed that hydrodynamically connect waters from fractures and fracture-veins, causing their complex mineralization, chemical and gas composition across the entire studied area.

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A geographical dimension of resource endowment of Ukrainian territories

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Abstract. Given the multidisciplinary nature of this research, it is important to develop a common understanding of the security and complexity of the rational consumption of available minerals. Considerations for the availability and depletion of minerals are part of a diverse range of research focused on sustainable development, in areas such as resource critical shortage, life cycle assessment and material flow analysis. Mineral resources are non-renewable resources that provide humanity with a wide range of goods and services. Although their value has been recognized for millennia, their large-scale industrial production did not grow until after World War II due to efficient industrial production processes and rapidly growing demand due to demographic growth, urbanization and economic wealth growth in developed countries. The proposed research confirms the high level of supply of the territory of Ukraine with mineral resources. The objective idea of mineral and self-sufficiency of Ukraine, its inclusion in the top groups of the states most provided with the most valuable types of minerals is strengthened and the high level of availability of mineral resources in Ukraine in terms of its economic and geographical areas and regions is confirmed. At the same time, a number of mineral deposits in modern social and economic conditions are preserved and not used. For the first time, a cartographic interpretation of the periodic table of chemical elements (D. I. Menedeleev's table) is given, which is reinforced by data on the distribution of mineral resources and minerals in terms of selected groups of regions within the administrative regions of Ukraine. There are 33 chemical elements extracted from more than 100 mineral deposits. The provisions and conclusions of the article testify the mineral self-sufficiency of Ukraine and can act as a lever for developing strategies for socio-economic development of the United Territorial Communities (UTC) of Ukraine, which today are the new centers of management of territories and its resources. D. I. Mendeleev's table and its mineral content are positioned as an objective factor in the specialization of Ukraine and the international geographical division of labour. It is noted that the main advantages of the Periodic Table of Chemical Elements, including its structure, logic, objectivity, a system in relation to the economic and geographical regions of Ukraine are considered as an element of monitoring the mineral component of natural resources of the country, the lever of further development of exploratory geology and geomorphology. The information obtained from this research ultimately influences the future policies of the territories and its plans for the balanced use of available mineral reserves and can be used to promote the sustainable use of mineral resources in the regions.

Keywords: mineral resources of Ukraine, minerals, deposits, system of chemical elements, table DI Mendeleev, cartographic interpretation, region, district, United Territorial Communities (UTC).

Географічний вимір ресурсозабезпеченості територій України

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Анотація. З огляду на мультидисциплінарний характер даного дослідження, важливо сформувати загальне розуміння стану забезпеченості та складності раціонального споживання наявних корисних копалин. Міркування щодо доступності та виснаження корисних копалин є частиною різноманітного спектру досліджень, орієнтованих на сталий розвиток, у таких сферах, як критичність ресурсів, оцінка життєвого циклу та аналіз матеріального потоку. Мінеральні ресурси є невідновлюваними ресурсами, що забезпечують людству широкий спектр товарів і послуг. Хоча їх цінність визнавалась тисячоліттями, масштаби видобування мінеральних ресурсів справді зросли лише після Другої світової війни завдяки появі ефективних виробничих процесів та швидкому збільшенню попиту, зумовленому демографічним зростанням, урбанізацією та збагаченню розвинених країн. Пропоноване дослідження демонструє високий рівень забезпечення території України мінерально-сировинними ресурсами. Вперше дана картографічна інтерпретація періодичної таблиці хімічних елементів (таблиця Д. І. Менделєєва), яка посилена даними щодо розподілу мінерально-сировинних ресурсів та корисних копалин в розрізі виділених груп регіонів в межах адміністративних областей України. Наведено 33 хімічні елементи, які видобуваються на понад 100 родовищах корисних копалин. Положення та висновки статті засвідчують мінерально-сировинну самодостатність України та можуть виступати важелем розробки стратегій суспільно-економічного розвитку об'єднаних територіальних громад (ОТГ), які сьогодні є новими центрами управління територіями та її ресурсами. Таблиця Д. І. Менделєєва та її мінерально-сировинне наповнення позиціонуються як об'єктивний чинник спеціалізації України та міжнародного географічного розподілу праці. Інформація, отримана в результаті

цього дослідження, зрештою впливає на подальшу політику територій та її плани щодо збалансованого використання наявних запасів корисних копалин і може бути використана для сприяння сталому використанню мінеральних ресурсів у регіонах.

Ключові слова: мінерально-сировинні ресурси України, корисні копалини, родовища, система хімічних елементів, таблиця Д. І. Менделєєва, картографічна інтерпретація, регіон, район, об'єднані територіальні громади (ОТГ).

Relevance of the research topic.

The need for local government reform and territorial organization of power in Ukraine was due to the fact that the administrative-territorial system in the country did not meet the modern requirements of real transformation, hindered the necessary transformations in the state, and due to effective regional policy, which resulted in restraining the development of individual territories and the state as a whole. The "Strategy of sustainable development of Ukraine until 2030" approved by the Decree of the President of Ukraine provides for a comprehensive approach to reforms in Ukraine. Clause 9 of the Strategy outlines an energy saving program, which states "ensuring the widest possible diversification of ways and sources of primary energy resources, including oil, natural gas, coal, nuclear fuel, increasing domestic energy production" (Strategy of sustainable development of Ukraine until 2030, 2017). The strategy of sustainable development, together with the new administrative-territorial structure proclaimed at the state level, should become the basis for creating a new model of territorial governance. To implement effective management of territories, and resources in particular, at the local level, there is a need for a detailed assessment of the resource security of the territories of Ukraine and further formation of the methodological framework for improving the territorial organization of government in their management.

Sustainable development of mineral resources is important for the national strategy of resource endowment and environmental civilization. Rational use of mineral resources, based on the model of ecological safety of the landscape, forms a scientific basis for overcoming conflicts between the conservation of resources and their use by man, contributing to the accompanying economic development and ecological integrity. Rational use of mineral resources, based on the model of ecological safety of the landscape, forms a scientific basis for overcoming conflicts between the conservation of resources and their use by man, contributing to the accompanying economic development and ecological integrity.

Diagnostics of mineral base and self-sufficiency of Ukraine, monitoring of the natural resource environment, and the state of its subsoil is an important factor in the economic stability of the state. A component of this scientific and practical issue is the expansion and deepening of systemic ideas about the location of geochemical raw materials in Ukraine by grouping united territorial communities (UTC) by region, using tables of chemical elements as a basis for a fundamental methodological approach.

This issue study state and main works.

A review of analytical publications and publications on the critical description of the availability and extraction of minerals, identified a significant expansion of the scope of research in the context of balanced use of their available reserves. This can be used to promote sustainable consumption of mineral resources in the regions: from mining, landscape change, and pollution to ecosystem health, sustainable development, and the rights of future generations (Christmann, 2018; Contested terrain: Mining and the Environment, 2004; Northey, Mudd, Werner, 2018; Peng, Zhou, 2019; Zhang, Wang, 2020). A significant array of publications of domestic and foreign specialists – geologists, geographers, naturalists – is devoted to the mineral resources of Ukraine, deposits of its minerals (Gursky, Esipchuk, Kalinin, 2006; Beydik, 2018, 2019; Rudko, Ivanov, Kovalchuk, 2019). On the other hand, the ingenious invention of D. I. Mendeleev, his periodic table of chemical elements for over a hundred years is at the center of both world scientific thought and practical development of the strategies laid down in it, because instead of scattered, unrelated compounds, appeared before science the only coherent system that combines all the chemical elements. Strengthening the table with examples of specific mineral deposits of Ukraine was reflected in the works of Beydik O. (Beydik, 2018, 2019), and the characteristics of mineral deposits of Ukraine are given in a number of fundamental sources (Geology of the USSR, 1958; Gursky, Esipchuk, Kalinin, 2006; Restructuring of the mineral resources base of Ukraine and its information support, 2007; Rudko, Ivanov, Kovalchuk, 2019). Suggested material is an attempt of mineral-raw material and economic-geographical strengthening of D. I. Mendeleev's table, demonstration of interdisciplinary connections at studying the geography of Ukraine and the natural-resource self-sufficiency of the country.

Formulation of the problem.

Resource management is perhaps the most important condition for the functioning of any complex territorial systems of different levels. In the analysis and assessment of the quality of management use the concept of "production and resource potential", the study of its size and structure. This concept defines the maximum potential of accumulated and prepared for processing

natural, logistical, labor, financial and information resources to meet the needs of the individual citizen and society as a whole. The results of the assessment of all resources, especially natural (raw materials), will form the main direction of the strategy of management of the territory and available resources. In the context of modern market demand resource conservation (which is to reduce resource consumption, use active resource-saving measures, support competitive positions based on reducing resource use and reducing resource consumption), new centers of management of territories and its UTC resources, according to current legislation have the opportunity not only to influence and optimize this process but also to have from this revenue to the budget (Chykalo, 2018). Resources of UTC territories can be grouped as follows:

a) natural-geographical: land, forest, water, mineral, biological, energy;

b) social and economic: tangible (movable and immovable property, communications), financial (budget revenues and expenditures, grants, subventions, grants), human, and intangible (information, technology, communications).

Thus, ***mineral resources*** (fuel and energy, ore, chemical raw materials, natural building materials, and non-metallic minerals), in our opinion, can provide the greatest opportunity to ensure financial capacity and self-sufficiency as separate UTC, and regions (oblasts) of Ukraine, which remain the largest administrative-territorial units in Ukraine.

There are a significant amount of natural or artificially created various substances (chemical elements and compounds, alloys, solutions, polymers) on the Earth. The distribution of chemical elements and mineral deposits on Earth is heterogeneous. This heterogeneity is reflected in the chain of security levels of mineral resources of countries and territories: very low, low, medium, high, very high. The extreme links in this chain can be represented, for example, by Paraguay (very low level of mineral supply) and South Africa (very high level of mineral supply). According to various estimates, Ukraine occupies the third (middle) – fourth (high) step in this line. We will remind that in the bowels of Ukraine about 20 thousand deposits and displays of 117 types of minerals are found out, from which 8291 deposits of 97 types of minerals are of industrial value and considered by The State Reserves. Mineral resources of Ukraine largely determine the national division of labor, Ukraine's place in world production of mineral resources. According to the potential value of confirmed mining reserves in the subsoil, it ranks 12th in the world (2.2 % of the potential value of world reserves) (Restructuring of the mineral resources base of Ukraine and its information support, 2007). As for energy, according to some experts, historically Ukraine has huge resources – both oil and gas. This publication is an objective basis for such fundamental assessments and aims to demonstrate the country's self-sufficiency in providing the most important minerals.

The purpose of the study is to adapt the periodic table of chemical elements of D. I. Mendeleev for the systematization of ideas and cartographic modeling of the distribution of mineral deposits in the context of the regions of Ukraine. Positioning and realization of the goal serve as an evidence base of the mineral and self-sufficiency of Ukraine. To propose the grouping of UTC regions within the administrative regions of Ukraine according to the level of security of mineral deposits for optimizing the structure of the socio-economic complex of Ukraine and all its components, taking into account the provision of geochemical raw materials of a particular area, which is crucial in the formation and development of specialization, complexity, balance, and proportionality.

Research methods.

The system approach and methods of deductive, comparative geographical (analysis of maps of minerals, mineral resources of Ukraine in terms of administrative regions) analysis, mapping and cartographic modeling (cartographic interpretation of D. I. Mendeleev's table), monographic (analysis of fundamental works of leading domestic and foreign geologists and resource scientists, geological and mineral directories and dictionaries, multi-volume publications on geology and mineral resources of Ukraine) were used when the article was been writing, and modern computer technologies (Arc GIS Online, Adobe Illustrator CC) were used in data processing and systematization. Both GIS technologies and classical methods of cartographic imaging (localized icons, cartograms and map diagrams) were used in the creation of cartographic models.

Presenting main material.

In terms of theory and practice, the geographical map plays an important role both at the beginning of any study, when its fundamental paradigm is laid, and at the end, when the certain elements of integration of zoning components, its configuration and contours are deepening, clarifying or refuting. The analysis of theoretical bases, principles, criteria of grouping of territory (regions) as a whole and regional schemes of Ukraine showed some variability in scientific and practical approaches and results of this procedure (Alampiev, 1963; Christmann, 2018; Contested terrain: Mining and the Environment, 2004; Palamarchuk, 1993; Popovkin, 1993; Dolishnyi, Palamarchuk, Palamarchuk, Shevchuk, 1997; Shabliy, 2000).

Grouping is one of the main methods of studying spatial phenomena, a lever and a factor in solving a

number of scientific and practical problems. In the active period of implementation of the decentralization reform, severance of industrial relations, and the actual liquidation of economic and geographical areas, the scientific and practical significance of the last one remains less noticeable. The main idea of grouping UTC within the administrative regions of Ukraine was to optimize the structure of the social and economic complex and all its components, taking into account the supply of geochemical raw materials of a particular area, which is crucial in the formation and development of specialization, complexity, balance, and proportionality. When mastering the material, the basic data on new administrative-territorial units is territorial communities and districts in various formats on the portal "Decentralization" were analyzed.

Thus, we have identified three groups of UTC regions within the administrative regions in terms of the level of mineral deposits:

1) *Highly resource level regions* (Donetsk, Luhansk, Zaporizhia, Dnipropetrovsk, Lviv, Ivano-Frankivsk, Zakarpattia, Chernivtsi, Odessa, Mykolaiv, Kherson, Crimea);

2) *Middle resource level regions* (Kyiv, Chernihiv, Volyn, Rivne, Zhytomyr, Vinnytsia, Khmelnytsky, Ternopil);

3) *Low resource level regions* (Kirovohrad, Cherkasy, Kharkiv, Poltava, Sumy).

A systematic idea of providing Ukraine with mineral resources both as a whole and by groups of regions is given by the figure "Scheme of distribution of available and latent chemical elements of the periodic table groups of UTC regions within the administrative regions of Ukraine" (Fig. 1) and an explanation in the table "Mineral deposits by regional groups of Ukraine" (Table 1).

Chemical elements free state appear very rarely, more often they are part of various compounds, so we consider them as components of the most common minerals in Ukraine, for example, copper (Cu) is part of chalcocite (Cu2S), tetrahedrite (Cu12Sb4S 13), chalcopyrite (CuFeS 2); lead (Pb) is a part of galena (PbS), boulangerie (5PbS * 2Sb2S 3), cerusin (PbCO3); silicon (Si) is part of quartz (SiO2), opal (SiO2*n H2O), chalcedony (SiO2), staurolite (Fe [OH] 2 * 2Al2SiO5) and twenty others. It concerns every element. Various combustible hydrocarbons of the type (CH3 and CH4) in the mixture are the part of the oil. Inert elements are an integral part of combustible gas.

As can be seen from the Table 1, more than 30 chemical elements are extracted at more than 100 mineral deposits.

Table 1. Mineral deposits by regional groups of Ukraine

Elements of rock-forming minerals	Rock-forming minerals	The main deposits
Aluminum	bauxite, alunite, staurolite, pyrophyllite, augite, epidote, spesartine, almandine, pyralspit	Prydniprovya (Vysokopilske, Smilyanske, Kremenchuh, Kryvyi Rih), Donbass (Chasivyarske), Crimea (Karadag), Volyn (Ovruch), Pobuzhya
Barium	barytes	Zakarpattia (Behanske), Donbass (Nagolny Kryazh), Zhytomyr region (Golovynske, Turchynske)
Carbon	diamonds, graphite, calcite, magnesite, dolomite, siderite, smithsonite, aragonite, cerusin, malachite	Prydniprovya (Zavalske, Petrivske, Pravdynske, Kryvyi Rih), Donbass (Mykytivske, Nagolny Kryazh, Slovyanske), Crimea (Baidaratske, Kerch peninsula), Zakarpattia (Trebushanske, Buzhanske, Berehivske)
Iron	pyrrhotite, chalcopyrite, pyrite, marcasite, arsenopyrite, hematite, magnetite, chromite, ilmenite, goethite, limonite, siderite, vivonite, staurolite, olivine, augite, egerin, muscovite, biotite, vermiculite, epidote, chlorite	Crimea (Kerch Peninsula), Donbass (Nagolny Kryazh, Mykytivske), Prydniprovya (Kryvyi Rih, Kapitonovske, Lipovenkivske, Samotkanske, Volynske, Serednyodniprovske, Kremenchutske)
Gold	-	Dnipropetrovsk region (Nikopol district, Chortomlyn geological structure), Zakarpattia (Muzhievo)
Potassium	alunite, muscovite, biotite, lepidolite, sylvin, nepheline, feldspars	Donbass (Chasivyarske) Prydniprovya (Vysokopilske, Smilyanske), Western Priazovye, Zakarpattia (Berehivske), Prykarpattya (Kaluske, Stebnytske)
Calcium	calcite, dolomite, aragonite, anhydrite, epidote, diopside, augite, fluorite, chabazite, titanite	Crimea (Baidaratske), Donbass (Slovyanske), Zakarpattia (Dilovetske, Buzhenske), Volyn, Prykarpattia, Pobuzhye, Chernihiv, Ivano-Frankivsk, Khmelnytsky oblasts, Transnistria
Silicon	quartz, opal, chalcedony, staurolite, olivine, pyralspit, almandine, spesartine, epidote, diopside, augite, aegirine, talc, pyrophyllite, chlorite, muscovite, biotite, lepidolite, verminulite, topaz, titanite, zircon	Donbass (Nagolny Kryazh), Volyn (Ovruch), Crimea (Karadag), Pobuzhye, Priazovya, Zakarpattia, Prydniprovya (Kremenchuk, Kryvyi Rih, Samotkanske)
Lithium	lepidolite	Transnistria

Elements of rock-forming minerals	Rock-forming minerals	The main deposits
Magnesium	magnesite, dolomite, olivine, pyralspit, diopside, augite, talc, chlorite, biotite, bischofite, vermiculite	Middle Prydniprovya (Kryvyi Rih, Pravdyn), Priazovye, Carpathians, Volyn, Pobuzhye, Crimea
Manganese	pyrolusite, manganite	Prydniprovya (Nikopol, Ingulets), Carpathians
Arsenic	realgar, auripigment	Donbass (Mykytivske), Crimea (Kerch Peninsula), Zakarpattia (Kvasy)
Copper	malachite, azurite	There are no estimated deposits, there are only ore occurrences: Donbass (Nagolny Kryazh, Mykytivske), Priazovya (Maloyanisonske), Zakarpattia, Volyn, Podillya, Prydniprovya
Molybdenum	in the composition of molybdenite	Donbas, Prydniprovya
Sodium	nitrate, mirabilite, aegirine, nepheline, halite, feldspars	Volyn, Priazovya, Kryvyi Rih, Middle Prydniprovya, Prykarpattia (Kalush-Stebnytske deposit)
Nickel	nickel, millerite, pentlandite	Middle Prydniprovya, Pobuzhzhya (Derenyukhske, Lipovenkivske)
Tin	cassiteritis	Prydniprovya
Platinum	platinum group metals (palladium, iridium, rhodium, osmium, ruthenium)	Dnipropetrovsk oblast (Nikopol district, Chortomlyn geological structure)
Mercury	cinnabar	Donbass (Mykytivske), Zakarpattia and Crimea
Lead	galena, bulanerite, cerusite	Donbass (Nagolny Kryazh), Prykarpattia, Zakarpattia (Berezivske, Vyshkivske, Beregivske)
Sulfur	free state, chalcosin, galena, sphalerite, pyrrhotite, chalcopyrite, cinnabar, antimonite, realgar, auripigment, molybdenum, pyrite, marcosite, arsenopyrite, boulangerite, tetrahedral, barite, celestine, anhydrite, gypsum, mirabilite	Prydniprovya (Vysokopilske, Smilyanske), Donbass (Mykytivske, Nagolny Kryazh), Crimea (Kerch Peninsula), Transnistria (Rudalske, Yazivske, Lyubinske, Humenetske), Prykarpattia (Kaluske, Stebnytske)
Silver	-	Donetsk oblast (Naked ridge), Zakarpattia (Kvasivske)
Strontium	celestine, strontium	Prykarpattia, Podillya
Trumpet	antimonite, tetrahedral, bulanerite	Donbass (Mykytivske, Nagolny Kryazh), Zakarpattia
Titanium	ilmenite, rutile, augite, titanite	Zhytomyr oblast (Irshanske), Zakarpattia, Carpathians, Pobuzhye, Crimea, Priazovye, Central Prydniprovya (Samotkansky, Volyn, Middle Dnieper)
Zinc	zinc deception	Donbass (Nagolny Kryazh), Prykarpattia (Truskavets district), Zakarpattia (Berehivske, Vyshkivske, Berezivske)
Chrome	chromite, celestine	Middle Prydniprovya (Kapitonovske, Lipovenkivske), Volyn, Priazovye, Kryvyi Rih
Fluorine	fluorite, muscovite biotite, lepidolite, topaz	Vinnytsia region (Mogilev-Podolsky district), Western Priazovye, Volyn, Dnipro, Ivano-Frankivsk and Chernihiv regions, Donbass
Phosphorus	apatite, vivonitis	Donbass (Osykivske), Prydniprovya (Novopoltavske), Chernihiv and Khmelnytsky regions, Crimea (Kerch peninsula)
Chlorine	halite, sylvin	Donbass (Slovyanske, Artemivske), Prykarpattia (Kaluske, Stebnytske), Zakarpattia
Zirconium	zircon	Prydniprovya (Samotkanske, Rozsypne), Priazovya
Volatile hydrogen compounds	_	Poltava oblast (Hlynsko-Rozbyshivske), Sumy oblast (Kachanivske, Rybalske), Chernihiv oblast (Gnidyntsivske, Lelyakivske), Ivano-Frankivsk oblast (Dolynske), Lviv oblast (Truskavets, Boryslav)
Inert gases	_	Crimea (Glebivske, Dzhankoyske), Kharkiv oblast (Shebelinka), Poltava oblast (Gogolivske, Solokhivske), Dnipropetrovsk oblast (Bereshenine), Lviv oblast (Rudkivske, Khodnovytske)

The above was "converted" into a cartographic model, which is an interpretation of the periodic table of chemical elements (Fig. 1).

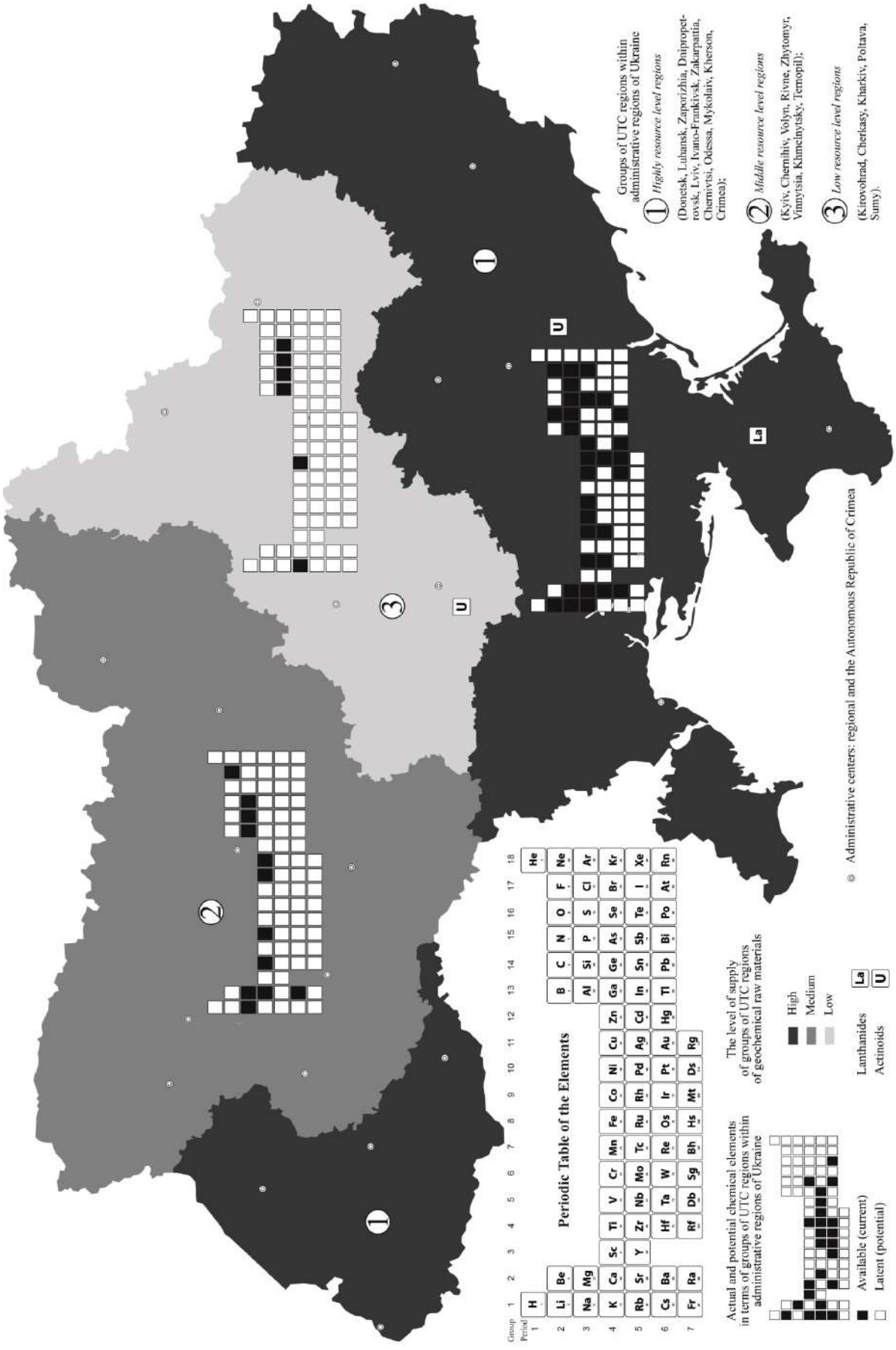

Fig. 1. Scheme of distribution of available and latent chemical elements of the periodic table by UTC groups within the administrative regions of Ukraine

The constructed map with relatively smaller / larger differentiation of available chemical elements of the periodic table demonstrates the potential of selected groups of UTC within administrative regions with relatively high concentrations of minerals, which indicates not only valuable actual deposits, but also high mineral potential of these areas (latent deposits). At the same time, a significant share of the largest European country still remains a mineral resource terra incognita, the subsoil of which is still awaiting for their use. Isn't this a fundamental factor that will give Ukraine optimism about its future? The main advantages of the periodic table of chemical elements, including its structure, logic, objectivity, regularity in relation to groups of regions within administrative regions are considered as an element of monitoring the mineral component of the country's natural resources, a lever for further development of exploratory geology and geomorphology.

Thus, D. I. Mendeleev's table enhanced by distribution data of mineral resources and minerals in terms of selected groups of UTC within the administrative regions of Ukraine is presented clearly. It should be noted that the cartographic and textual information contained in the article is open for interpretation and further steps to deepen and expand the idea of qualitative and quantitative analysis of the most important national and regional mineral deposits.

Conclusions and results.

A cartographic interpretation of the periodic table of chemical elements (D. I. Mendeleev's table) is presented for the first time, which is reinforced by data on the distribution of mineral resources and minerals in the regions of Ukraine and were formed into three groups within administrative regions: high, medium and low-income regions. The objective idea of Ukraine's mineral base and self-sufficiency is strengthened. The uneven distribution of the available chemical elements of the periodic table on the territory of Ukraine was confirmed, the potential of the selected UTC groups within the administrative regions of Ukraine for relatively smaller / larger differentiation by chemical elements of the periodic table was demonstrated through the map. At the same time, it should be noted that a number of mineral deposits in modern social and economic conditions are preserved and not used. Information on geochemical raw materials available in Ukraine is systematized according to three items (elements of rock-forming minerals – rock-forming minerals – main deposits), which update the cartograms and map diagrams placed on the diagram. D. I. Mendeleev table and its mineral content are positioned as an objective factor in the specialization of Ukraine and the international geographical division of labor. The presented material substantiates the mineral base and self-sufficiency of Ukraine and can act as a lever for the development of new strategies for social and economic development of particular UTCs of Ukraine. The study can be continued in the following areas: the study of public policy on the design of balanced use of mineral resources and the distribution of costs for the development of resources; research in the field of external control, resource rights, and environmental justice; cultural studies that illustrate how mining affects public concern about the social and environmental consequences of national (and global) industrialization and globalization.

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Spatial analysis of natural reserve fund of the Zakarpatska Oblast

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Abstract. The article brings light to the study of the nature reserve fund (NRF) of Zakarpatska oblast as a component of the national heritage of the country. Representativeness is considered to be one of the main principles of spatial formation of the NRF object network. Therefore, to determine the current state and ensure further effective development of the region's nature reserve fund, it is necessary to analyze its territorial and internal structural indicators. The purpose of the study is to analyze the current status of the region's nature reserve fund with the reference to the possibility of introduction of the further new management practices. The article is based on information and statistical materials, the provisions of regional programs for the formation of the ecological network and environmental legislation of Ukraine. To solve the assigned tasks, there has been done a comprehensive analysis of statistical reporting data and materials of the NRF Register in Zakarpatska oblast of the Department of Ecology of Natural Resources of Zakarpattia Regional State Administration within the period of 2019, and reporting documents of environmental institutions for the same period. The considered indicator is the territorial distribution of nature reserve areas and region areas by administrative districts (before the formation and implementation of changes to the administrative-territorial structure of the Zakarpatska oblast), which is presented in the form of the division into four groups. The spatial distribution of the territory and the NFR objects do not sufficiently meet the criteria of local representativeness, so their spatial structure needs significant improvement, be specific – the creation of nature reserves, especially in the lowlands of the region. The average density of nature protection objects in the region (36 units / 1000 km^2) is almost three times higher than the corresponding indicator in the neighboring Lviv region. The average value of the reserve factor in the region makes 14.17 %. It has been found that the reserve ratio demonstrates geographically the largest disproportion in Zakarpatska oblast. It is the highest indicator in turns of administrative entities in the districts of Mizhhiria, Velyky Bereznyi and Rakhiv. The lowest one is in Svaliava and Berehove districts, respectively. In addition, the reserve ratio compared to the national average indicator and in other European countries has been carried out. The quality of the nature reserve network is determined by the insularity coefficient, which indicates the size of the NRF objects and their stability. Further expansion of the network of nature protection objects in Zakarpatska oblast is possible due to the creation of Latorytsa, Shaian and Uzhok landscape parks. A big assumption can be made that by 2020 it will be possible to create new and expand existing areas of NRF in the region up to 100–120 thousand hectares, which will increase the protected area up to 20–22 %. The key issues of nature reserves to be developed in Zakarpatska oblast are primarily related to the imperfection of the management system. To handle this problem, there is an urgent need to develop a strategy, which will envisage the perception of the NRF as a holistic anthropogenic and natural unit in order to put into practice the environmental, scientific, educational and recreational functions.

Keywords: nature reserve fund (NRF), density of nature protection objects, reserve factor, index of insularization, Zakarpatska oblast

Просторовий аналіз природно-заповідного фонду Закарпатської області

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Анотація. Стаття присвячена дослідженню природно-заповідного фонду (ПЗФ) Закарпатської області як складової національного надбання країни. Одним із головних принципів просторового формування мережі об'єктів ПЗФ є репрезентативність. Тому для визначення сучасного стану та забезпечення подальшого ефективного розвитку природно-заповідного фонду регіону необхідно здійснити аналіз його територіальних та внутрішньо-структурних показників. Метою дослідження є проведення аналізу сучасного стану природно-заповідного фонду області щодо можливостей запровадження в подальшому нових практик управління. Здійснено оцінку його територіальних та внутрішньо-структурних показників, на основі якого можна судити про рівень сформованості сучасної природно-заповідної мережі області. Розглядається розподіл територій та об'єктів ПЗФ Закарпатської області за їх значенням, категоріями та типами. Розраховано щільність об'єктів ПЗФ, коефіцієнт заповідності та індекс інсуляризованості. На основі цих показників проведено групування адміністративних районів області ще до початку формування та впровадження змін до адміністративно-територіального устрою Закарпатської області. З'ясовано, що коефіцієнт заповідності демонструє найбільшу диспропорцію в територіальному відношенні у межах Закарпатської області. Крім того, здійснено порівняння коефіцієнта заповідності з середнім показником по країні та іншими країнами Європи. Якість природно-заповідної мережі визначено за допомогою коефіцієнта інсуляризованості, що засвідчує величину об'єктів ПЗФ та їхню стійкість. Акцентується увага на перспективі подальшого розширення мережі природно-заповідного фонду Закарпатської області за рахунок створення нових природоохоронних об'єктів, зокрема, Латорицького, Шаянського та Ужоцького ландшафтних парків, та розширення меж уже існуючих природозаповідних територій. Окреслені основні проблеми розвитку заповідної справи в області на сучасному етапі. Існує нагальна потреба щодо розробки стратегії, яка передбачатиме сприйняття ПЗФ, як цілісного антропогенно-природного організму з метою практичного втілення природоохоронної, науково-освітньої та рекреаційної функцій.

Ключові слова: природно-заповідний фонд, щільність об'єктів ПЗФ, коефіцієнт заповідності, індекс інсуляризованості, Закарпатська область

Introduction.

A prominent place in the structure of territories and objects, which have the status of special legal protection, is given to the nature reserve fund of Ukraine (hereinafter – NRF). NRF is characterized by a special mode of protection, reproduction and use. Thus, the Law Ukraine "On Environmental Protection" states that natural areas and objects that are of great ecological value as unique and typical natural complexes under special state protection (Zakon Ukrainy "Pro okhoronu navko lyshnoho pryrodnoho seredovyshcha", 1991). Well-known American scientist Eugene Odum noted that to maintain the basic functioning of ecosystems and landscapes, it is necessary to preserve two-thirds of the territory in its natural state, while in Europe the area of protected areas is about 20 %. The nature reserve fund of European countries is almost 98 % concentrated in specialized ecological networks. As a national heritage of the NRF of Ukraine is a component of the world system (formation) of protected areas and objects, so it is necessary to implement the experience of European countries in land use of nature reserves, namely in terms of ecological networks.

In 1992, European legislation significantly broadened the understanding of the environmental protection problem, as a result of which the European program "Nature 2000" was developed – a system of special protected areas for wildlife conservation in Europe (Pietrzyk-Sokulska, 2009). A study of the experience of neighboring Poland in the operation of the nature reserve fund indicates differences in the level of financial and logistical support, in particular, some funding for Polish parks is provided by the European Union, as well as the principles of land use in such facilities. Despite the differences in the functioning and structure of the NRF between the two countries, they outline common goals, that is the preservation and balanced use of nature reserves. It is also necessary to take into account the European trends in the creation of geoparks, but the prospects for the use of such facilities for geotourism purposes, as shown by the experience of European countries in general and Poland in particular, are significant.

One of the main principles of spatial formation of the network of NRF objects is representativeness. Therefore, to determine the current state and ensure further effective development of the nature reserve fund of the region, it is necessary to analyze its territorial and intra-structural indicators.

Some aspects of the formation and development of nature reserves in Ukraine are considered in the works of: V. I. Hetman (Hetman, 2002), M. P. Stetsenka, F. D. Gamora (Stetsenko, Hamor, 2017), M. D. Grodzynsky (Hrodzynskyi, Sheliah-Sosonko, 2001), B. M. Girnogo, A. A. Kovalchuk (Kovalchuk, Ivanov, Sviderko, 2004; Kovalchuk, Pavlovska, Savchuk, 2011), O. Y. Kovalenko, D. V. Krylova, S. M. Stoiko (Stoiko, Hadach, Shymon, Mykhalyk, 1991) and others.

The main functions of the nature reserve fund are nature protection, scientific-education and recreation. The biosphere-ecological concept of sustainable development of TRS in their works was studied by L. Arkhipova, N. Fomenko, I. Kinash, O. Golovina (Arkhypova, Fomenko, Kinash, Golovnia, 2019). Various aspects of the formation, functioning and development of objects of the nature reserve fund of the Zakarpatska oblast, the assessment of its representativeness are found in the scientific works of S. M Stoiko (Stoiko, Saik, Tatarynov, 1982), F. D. Gamor, J. B. Oliynyk, V. I. Hetman (Oliinyk, Hetman, 2002), S. S. Pop (Pop, 2011), V. F. Antosyaka, N. F. Gabchak, L. F. Dubis, A. V. Melnyk, N. V. Chyr (Habchak, Dubis, Melnyk, Chyr, 2018), V. P. Kichuri, A. V. Kichura (2009),

V. V. Krichfalushiy, A. V. Mygaly, V. I. Nikolaychuk and others.

The purpose of the study is to analyze the current state of the nature reserve fund of the Zakarpatska oblast on the possibility of further introduction of new management practices. After all, at the present stage there is a growing social importance of nature reserves for the development of the state in general and the region in particular, which requires scientific justification by establishing the dynamics, identifying major trends and patterns of its development, as well as identifying and solving problems to ensure further effective development.

Materials and methods of research.

This article is based on information and statistical materials, the provisions of regional programs for the formation of the ecological network and environmental legislation of Ukraine. The study was conducted on the basis of analysis of statistical reports and materials data of the Register of NRF of the Zakarpatska oblast of the Department of Ecology of Natural Resources of the Zakarpatska Oblast State Administration for 2019 and reporting documents of environmental institutions of the region. The methodological tools of the study are presented by analytical, statistical, comparative-geographical, mathematical methods, as well as methods of generalization, systematization, classification and typology.

Methods of grouping and structuring were used to estimate the quantitative indicators of the NRF objects of the Zakarpatska oblast. Using the cartographic method, the territorial distribution and density of NRF objects were revealed. Research the qualitative characteristics of the NRF of the region of was carried out based on the insularity ratio, which proves the stability of protected areas (Klymenko, Olijnyk, 2014).

Results and their analysis.

Spatial-dynamic criteria for determining the representativeness of the natural funds are based on the statement that protected areas should be combined in space and time and have sufficient space to maintain biodiversity. Estimation of spatial-dynamic criteria is rather difficult. It is mainly based on qualitative characteristics, principles of functioning of eco-corridors, one of the important functions of which is to provide migration routes for the fauna.

To achieve the purposes of research on the possibilities of introducing new management practices natural commandments of Zakarpatska oblast it is necessary to analyze the total number of protected areas and their connection. It is, first of all, about the spatial organization of territories, which would ensure the integrity and effective protection of ecosystems, help to prevent artificial fragmentation of protected areas. In case of insufficiency of these characteristics it is necessary to solve questions concerning expansion of a network of NRF (Didukh, Vakarenko, Vynokurov, 2016).

The existing network of NRF of Ukraine was created mainly for the needs of protection of rare plants and animals, however, if we proceed from the idea that in modern conditions its objects should be the nuclei of a single ecological network, it is entrusted, among other things, the function of landscape and biodiversity. Thus, the prospects for improving the organizational and legal framework for the preservation of landscape and biotic diversity are primarily related to ensuring the combination of territories and objects of the NRF and other specially protected objects as part of a single multifunctional ecological territorial system (Udovychenko, 2017).

The urgency of the topic increases due to the need to create a Pan-European eco-network in the context of the Pan-European Strategy for Biodiversity Conservation (Sofia, 1995) as a result of combining eco-networks of different levels, forming an optimal structure of protected areas.

The key to creating conditions for the effective functioning of typical natural and unique landscapes, reducing the rate of loss of biological diversity is the formation of a representative, scientifically sound and holistic in spatial and functional aspects of protected areas (Chyr, 2016).

The current structure of the nature reserve fund of the studied area consists of 469 territories and objects on the total area of 180.6 thousand hectares (as of 2019) (Fig. 1). At the same time, 34 objects are of national importance (155.5 thousand hectares) and 435 objects of local importance (25.1 thousand hectares) (Department of Environment Natural Resources Zakarpatska oblast Regional Administration, 2019). The distribution of territories and objects of Zakarpatska oblast NRF by their meaning, categories and types are given in table. 1.

It should be noted that the area of the NRF of the Zakarpatska oblast of more than 185.3 thousand hectares does not fully reflect the real area of protected territories. Quite often, nature protection objects of the highest category of reserve include the territories of lower categories of nature reserve fund. Therefore, the actual area of the NRF of the region without duplication is 180.7 thousand hectares, which is 2.5 % less than the previous figure.

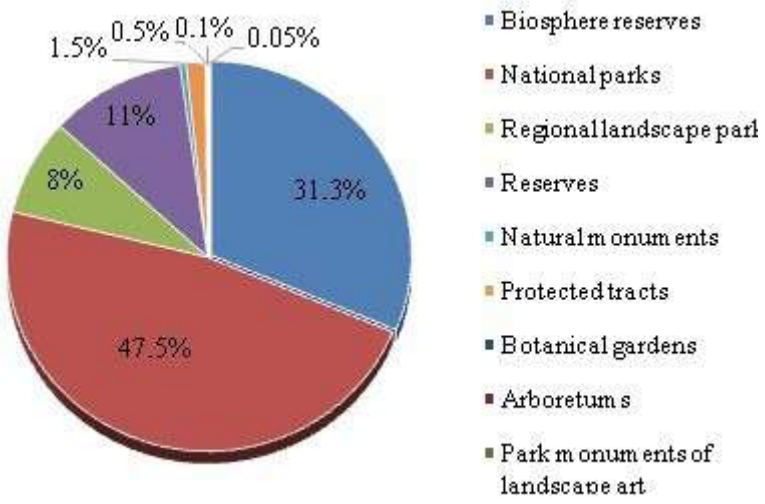

Fig. 1. The structure of the NRF of Zakarpatska oblast,% of the area of individual categories to the total area of the NRF (created by the authors on the basis of (Department of Environment Natural Resources of Zakarpatska Oblast Administration, 2019)

Table 1. The structure of the nature reserve fund of Zakarpatska oblast (as of 2019) (Department of Environment Natural Resources of Zakarpatska Oblast Regional Administration, 2019)

Categories of nature reserve fund	Objects of NRF						% of certain categories of the total area of NRF
	national importance		local significance		total		
	amount	area, hectares	amount	area, hectares	amount	area, hectares	
Biosphere reserves	1	58035.8	-	-	1	58035.8	31.31
National parks	3	87964.3	-	-	3	87964.3	47.46
Regional landscape parks	-	-	2	14961.9	2	14962.0	8.07
Reserves	19	12368.0 (9218.0*)	56	7935.5 (7098.9*)	75	20303.5 (16316.9*)	10.95
Natural monuments	9	464.0 (192.0*)	329	478.7 (384.3*)	338	942.7 (576.3*)	0.50
Protected tracts	-	-	12	2848.1 (2546.1*)	12	2848.1 (2546.1*)	1.54
Botanical gardens	1	86.4	-	-	1	86.4	0.05
Arboretums	-	-	2	34.9	2	34.9	0.02
Park monuments of landscape art	1	38.0	34	138.3	35	176.3	0.10
Total:	34	158956.5 (155534.5*)	435	26397.4 (25164.4*)	469	185353.9 (180698.9*)	100

Footnote: * – The actual area without duplication

As we can see, there is a certain disproportionate representation of different classification categories of protected areas in the NRF network of the region. At the same time, during their creation and further operation, attention is focused on the protection of individual components of nature, rather than the landscape as a whole. In addition, among all possible for the creation and defined by law a range of categories of NRF objects, the bequest of land took place mainly in the status of reserves and protected tracts of local importance, so they are quantitatively dominant in the region (Udovychenko, 2017).

Multifunctional objects of higher categories of reserves (Carpathian Biosphere Reserve, National natural park "Synevyr", National natural park Uzhansky Regional landscape park "Enchanted Land", Regional landscape park "Sinyak") make up the lion's share of the territories that have the status of protected areas (Fig. 2). Together, they occupy 87.3 % of the total area of the Zakarpatska oblast.

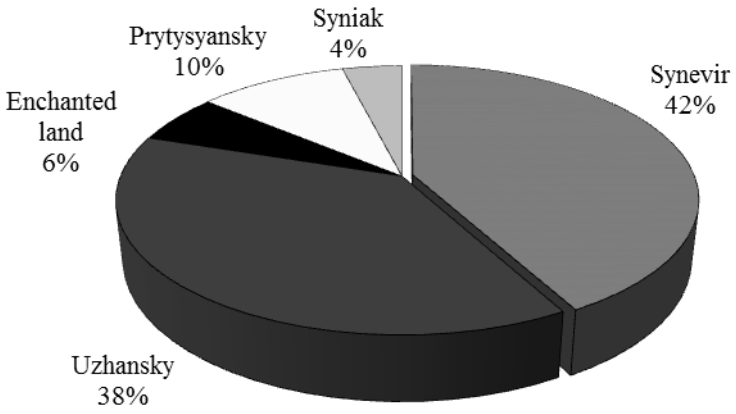

Fig. 2. Value space of the areas of the NRF objects of the Zakarpatska oblast of the highest categories of reserves (created by the authors).

Such protected areas are the destinations that attract tourists due to the availability of unique or specific tourist and recreational resources and appropriate infrastructure. However, special attention should be paid to the negative impact on the former environment due to the development of mass tourism, management of visitor flows, identification of sustainable types of tourism, the introduction of technologies to reduce the negative impact on the environment.

In recent years, Ukraine concerned mainly about improving the structure of NRF in quantitative manifestation, leaving aside its qualitative characteristics. Therefore, we consider it appropriate to investigate the qualitative characteristics of these areas.

In addition to the categorical distribution of the NRF of the region in accordance with the functions they perform, a qualitative reflection of the network of protected areas is the uniformity of their location.

The territorial structure of nature reserves and territories in the context of the administrative division of the region is quite representative. Analysis of their territorial structure shows a diverse distribution of protected areas in terms of administrative districts (studies are based on materials that preceded the reform to form a new administrative-territorial structure of the region), (Fig. 3) (Habchak, Dubis, Melnyk, Chyr, 2018).

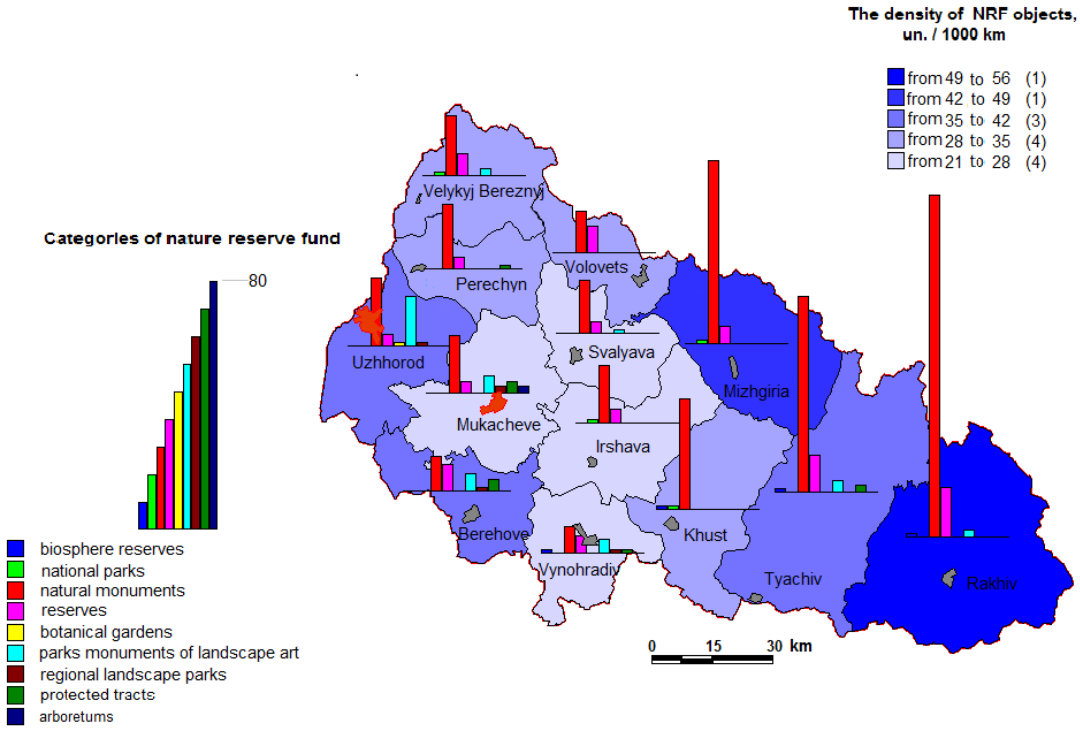

Fig. 3. Territorial structure of the nature reserve fund of Zakarpatska oblast

According to the assessment of quantitative indicators of NRF objects, the administrative units of Zakarpatska oblast are grouped as follows:

– Velykobereznyansky, Berehivsky, Vynohradivsky, Volovetsky, Irshavsky, Mukachevo, Perechynsky, Svalyava and Khust districts are territories with a small number of nature protection objects (up to 30 units);

– Uzhhorod, Mizhhirya and Tyachiv districts belong to the territories with a significant number of nature protection objects (30–60 units);

– Rakhiv district represents a group with a large number of environmental facilities (over 90 units). It accounts for 23 % of all NRF facilities in the region.

According to the indicator of spatial distribution of NRF areas, administrative units of Zakarpatska oblast can be grouped:

– Berehovo and Svalyava districts are the territories with a very small protected area (up to 1 thousand hectares);

– Volovets, Perechyn, Khust districts are the territories with a small protected area (up to 5 thousand hectares);

– Vynohradiv, Irshava, Mukachevo, Uzhhorod districts are the territories with large protected areas (5–10 thousand hectares);

– Velykobereznyansky, Mizhhirsky, Rakhiv, Tyachiv districts are the territories with a large protected area (over 10 thousand hectares).

The relative indicators, calculated in relation to the area of 1000 km², showed that the average value of the density of nature protection objects in the Zakarpatska oblast is (36 units / 1000 km²). For comparison: in the neighboring Lviv region the density of nature protection objects is fixed at the level of 10–15 units / 1000 km², which is almost three times lower than in the studied region (Kovalchuk, Ivanov, Sviderko, 2004).

Among the administrative districts, Vynohradiv and Mukachevo districts, as well as Berehiv, Tyachiv and Uzhhorod districts have the largest number of different objects and territories of the NRF, and Volovets district has the smallest number, respectively. In all administrative districts, except for Svalyava, objects and territories of both national and local significance are represented.

Uneven distribution of NRF in the region is a rather unfavorable factor for their main functions – biodiversity conservation. In general, this factor has a negative impact on the overall assessment of the NRF.

One of the important indicators of the quality of the nature reserve network of the region is the reserve ratio. Its average value in the region as of 2019 is 14.17 % (Department of Environment Natural Resources Zakarpatska Oblast Regional Administration, 2019). Despite the Program of long-term development of nature reserves and ecological network for 2006–2020, which declared an increase in the area of NRF of the region to 23 % due to the creation of objects of national importance, we note its insignificant negative dynamics (as of 2016–14.4 %) (Prohrama perspektyvnoho rozvytku pryrodno-zapovidnoi spravy ta ekolohichnoi merezhi v Zakarpatskii oblasti).

For comparison, the average rate of conservation in Ukraine is as of 2019–6.6 %.

Conservation, enhancement and sustainable use of ecosystem biodiversity has become one of the key environmental policy priorities of most EU countries. However, as for Ukraine, its current general reserve index is not only inferior to European standards (Fig. 4), but also does not meet the requirements of the Basic Principles (Strategy) of State Environmental Policy of Ukraine for the period up to 2020", adopted in 2011. According to them, in 2015 the area of the NRF was going to reach 10 % of the total territory of the country, and in 2020–15 % (Ecoinform, 2019). At the same time, the regulatory documents provide for an increase in the share of reserves in Ukraine to 15 % by 2020 (Yavorska, Hevko, Sych, Kolomiyets, 2018).

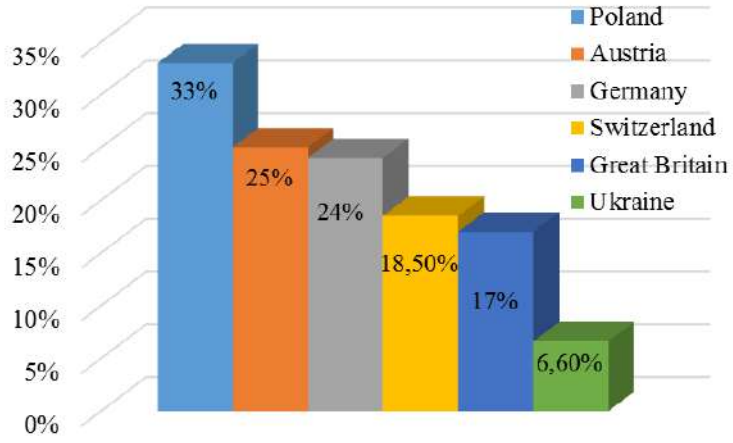

Fig. 4. Indicator of reserves of some European countries (created on the basis of (Ecoinform, 2019))

In addition to the low conservation rate, which is typical for the study area, there are a number of other important factors that hinder the growth of the reserve to European standards and standards regulations. In particular, it is about the probability of loss of the complexes which already exist and are reserved under the will of natural due to their withdrawal from the lands of the natural funds or misuse.

Meanwhile, not all sites can acquire the status of protected areas in accordance with European standards. It should be noted that the creation of protected areas in some areas of forests is a global trend and one of the key mechanisms for preserving their biological diversity. Today, almost 12 % of the world's forests already belong to such areas and are classified according to IUCN categories. The percentage of forest bequests in Ukraine (16.6 %) exceeds the corresponding figure of European countries (Ecoinform, 2019).

The reserve index shows the largest disproportion in the territorial relationship within the Zakarpatska oblast (Table 2). In particular, we fix the maximal value of this indicator in Velykobereznyansky, Rakhiv and Mizhhirya districts. Whereas, it is the smallest in Svalyava and Berehovo districts. This is explained by the specialization of these areas in health and recreational activities. At the same time, it is here that the emphasis should be on expanding existing and creating new environmental facilities.

Table 2. Quantitative indicators of the nature reserve fund in Zakarpatska oblast in terms of administrative units

Administrative district	Reserve rate,%	Density of NRF objects, un. / 1000 km	Index insularization
Berehivsky	1.2	38	0.57
Velykobereznyansky	48.7	31	0.44
Vynohradivsky	10.4	24	0.39
Volovetsky	6.3	33	0.34
Irshavsky	9.7	21	0.38
Mizhgirsky	35.9	46	0.46
Mukachevo	6.4	27	0.45
Perechynsky	5.1	33	0.44
Rakhivsky	23.2	56	0.46
Svalyava	0.5	27	0.51
Tyachivsky	8.5	36	0.45
Uzhhorod	7.1	40	0.44
Khustsky	4.8	30	0.49
Average regional indicator	14.4	36	0.44

Further expansion of the network of nature protection facilities within the Zakarpatska oblast is possible due to the creation of Latoritsky landscape park, where the sanatorium-resort complex "Kvitka Polonyny", "Sonyachne Zakarpattia", "Karpaty", Shayansky landscape park around Shayansky sanatorium is located. Uzhhorod Landscape Park (lower and middle part of the Uzh Basin), etc.

The need to expand protected areas is that currently protected areas border on intensively used agricultural land or adjacent to industrial areas. They are ecological islands surrounded by significantly changed natural conditions (Mudrak, Yelisavenko, Polishchuk, Mudr ak, 2019).

It will also be advisable to expand existing nature reserves. During 2014–2018, 10 objects of the nature reserve fund of local significance were created in the region on the total area of 2969.9 hectares. Of these, 7 reserves of local importance on an area of 1305.1 hectares and 3 protected areas on an area of 1664.8 hectares (Department of Environment Natural Resources Zakarpatska Oblast Regional Administration, 2019). In particular, in June 2015, the issues of expanding the territories of NPP "Enchanted Land" and "Synevir" were considered. The petition for the proposed changes to the boundaries of national nature parks was prepared by the Ukrainian Society for the Protection of Birds and approved by the Ministry of Nature of Ukraine.

In addition, in the future, the NRF of Vynohradiv district may increase due to the atonic reserve of local significance "Dombosh" (4.0 hectares); Tyachiv district – a forest reserve of local importance near the village. Ruske Pole (118 hectares) and a botanical reserve of local significance near the village of Neresnitsa (42 hectares). In the Uzhhorod district, it is planned to create a general zoological reserve of local significance along the Uzh River, as well as the botanical reserve "Ostrosh" (398.7 ha) and "Chernecha Hora" (40.0 ha) within the Mukachevo district. Hydrological reserves of local importance "Berezhskoe Reservoir" (46.0 ha), "Moshnev" (15.0 ha), "Dyidovskoe Reservoir" (75.0 ha); Gola Obuch and Solyansky forest reserves with a total area of 37 hectares, as well as the Borsuchy botanical reserve (up to 1.0 hectares) will replenish the protected areas of the Berehovo district in the future. Prepare Leno

scientific substantiation for creating a series of protected sites of local importance within Vinogradov District: botanical reserve "Dibrova Zatysyanschyny" "Fornoska Dubrava", "Travel" (Department of Environment Natural Resources Zakarpatska Oblast Regional Administration, 2019).

It is safe to assume that during the 2020s-2030s it will be possible to create new and expand the existing areas of NRF in the region up to 100–120 thousand hectares, which will increase the reserve area to 20–22 %. In general, it is planned to increase the nature reserve fund of Zakarpatska oblast to 23 % of its area.

The quality of the nature reserve network of the region is determined by the index of insularization, which indicates the size of the NRF objects and their stability. The high coefficient indicates a significant share in the territorial structure of the NRF of small, ecologically unstable, and therefore unstable protected areas. To this kind of environmentally unstable include protected areas with an area of up to 50 hectares (Klymenko, Olijnyk, 2014).

369 objects are located in the NRF of Zakarpatska oblast on the area of 614.4 hectares. Their area ranges from 0.01 to 51 hectares, and the average area is about 1.7 hectares. Such a large number of small objects with insufficient ecological capacity cannot fully ensure the preservation of the gene pool and living conditions of biota (Mudrak, Yelisavenko, Polishchuk, Mudrak, 2019).

Typically, such objects are represented in the structure of the NRF by botanical monuments of local character (which includes mainly age-old and old-fashioned root and introduced trees) or hydrological monuments of local character, including sources.

As a result of the research, it was established that the average value of the quality index of the NRF of the Zakarpatska oblast – the index of insularization is 0.44. This indicates the low quality of placement of the nature protection network (see Table 2). It should be noted that its significant fluctuations in administrative districts are not observed, the maximum value of the index is fixed at 0.56 for Berehovo district, its smallest value is 0.34 is typical for Volovets district (Fig. 5).

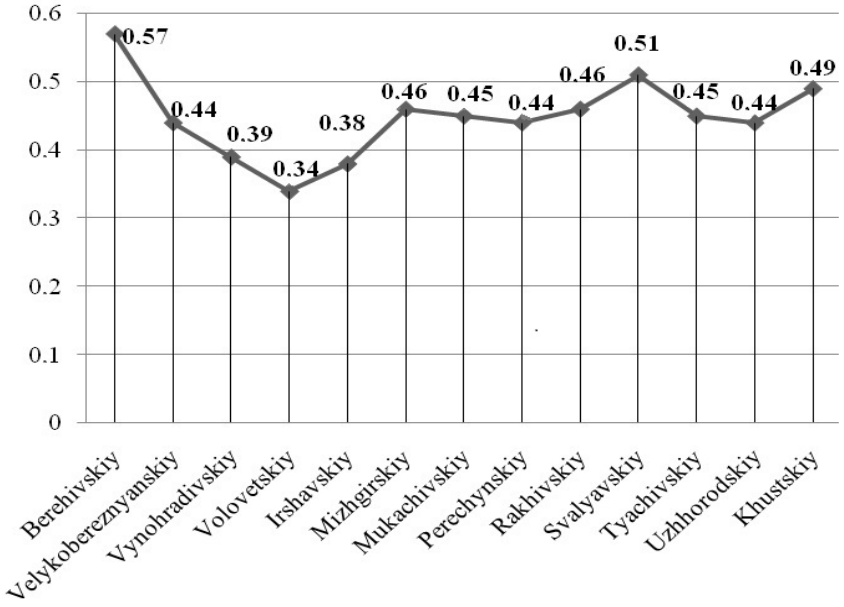

Fig. 5. Index of insularization of administrative districts of Zakarpatska oblast

Numerous small isolated protected objects and territories, which cannot always be combined due to the lack of conformity of the environment of isolates and connecting elements, are the result of a botanical approach to the reserve, which provides a well-conserved function to preserve species diversity of flora and fauna, only partially takes into account the need for systematic action of objects and territories of the nature reserve fund and almost does not provide a balance of environmental, economic and social requirements (Ivanov, Kovalchuk, 2007; Klymenko, Olijnyk, 2014; Kovalchuk, Ivanov, Sviderko, 2004). In accordance with the requirements of sustainable development, the region needs a comprehensive approach to nature conservation.

Despite the uneven spatial distribution, the nature reserve fund is represented in all existing landscapes and plant communities in the region of high-altitude zones. However, it should be noted that the majority of the areas account for the forest groups. About one-fifth of the forest land area is part of the region's NRF. Meadow, alpine and wetland plant groups make up 6.2–8.4 % in different parts of the region. As a result, protected areas have the opportunity to play the role of

a kind of key areas for maintaining ecological balance and reproduction of biological diversity.

The main problems of the development of protected areas in the region at the present stage, as in Ukraine in general, we associate, first of all, with the imperfection of the management system in this area, low budget funding, logistics, insufficient development of special research, weak legal liability for violation of the regime of nature reserves and facilities.

Conclusions.

The basis of the NRF of Zakarpatska oblast are multifunctional objects of the highest category of reserves. A large number of nature protection facilities is combined with their significant fragmentation, which affects the qualitative characteristics of nature reserves. According to the spatial distribution of the territory and objects of the NPF do not sufficiently meet the criteria of local representativeness, so their spatial structure needs significant improvement, namely – the creation of nature reserves, especially within the lower districts of the region.

At the present stage of development there is a clear tendency to increase the number and area of nature reserves and territories within the region. When planning new nature reserves in order to preserve landscape diversity, first of all, it is necessary to pay special attention to those areas where the most difficult situation has developed due to the small share of reserves.

The main problems of the development of nature reserves in Zakarpatska oblast are primarily related to the imperfection of the management system. To solve this problem, there is an urgent need to develop a strategy that will provide for the perception of NPF as a holistic anthropogenic-natural organism in order to put into practice the environmental, scientific, educational and recreational functions.

Qualitative functioning of the geoinformation system of monitoring of nature reserves of Zakarpatska oblast is designed to ensure effective management of environmental activities and rational use of nature in the region. It is due to the automation of processing, streamlining, generalization and integration of primary data, comprehensive analysis and evaluation of the representativeness of the nature reserve fund of Zakarpatska oblast and information-analytical decision support that it is possible to ensure further effective development of the nature reserve fund of the region, its representative taking into account the best European practices.

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