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BIOCLIMATIC AND HYDROMINERAL COMPONENTS OF NATURAL RECREATIONAL POTENTIAL OF THE CARPATHIAN REGION OF UKRAINE

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Abstract. Among the components of the natural recreational potential of the Carpathian region of Ukraine, a special place is occupied by bioclimatic and hydromineral resources, therefore the purpose of the work is to assess their features. The bioclimatic component of the natural recreational potential of this region determines the comfort (discomfort) of human sensations and well-being, so it is important to identify possible positive and negative impacts of various climatic factors and their dynamics in mountain and foothill areas during different seasons of the year. The bioclimatic component of the natural recreational potential is assessed from the point of view of the comfort of climatic conditions for the body of a healthy person. The work is based on the results of modeling the average daily values of air temperature (*t*), wind speed (*v*) and relative humidity (*f*) according to the RCP4.5 scenario (trajectory of changes in the average level of greenhouse gases concentration) from 2021 to 2050 and data from the climate cadastre of Ukraine (1961–1990) at three stations (Dolyna, Rava-Ruska, Uzhgorod) in the foothill areas of the region. There was conducted a study of the possible bioclimatic potential of the Carpathian region of Ukraine and trends of its dynamics until 2050. The article analyzes the features of mineral healing waters of four national nature parks of the Ukrainian Carpathians.

Keywords: bioclimatic conditions, hydromineral resources, mineral waters, natural resources, recreational potential, rehabilitation.

1. Introduction

One of the modern global problems is the warming of the climate and its impact on human life and health. In the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, it was noted that on a global scale, average aggregated data on land and ocean surface temperatures for the entire period of instrumental observations until 2012, determined on the basis of a linear trend, indicate a warming of 0.85 °C. The increase in temperature occurs unevenly on the earth's surface. The maximum increase in temperature is observed in the middle and subpolar latitudes of the Northern Hemisphere above the continents, where it reaches 1.7 and 2.0 °C, respectively, per century (Stocke et al., 2013). Changes in the global climate are accompanied by mostly negative consequences for the economy and living conditions of people, and they will intensify in the future, so it is necessary to look for ways to mitigate and develop measures to adapt to them (Field et al., 2014). The impact of climate change on human health is diverse. However, one of the greatest direct impacts on human health due to climate warming is expected to be an increase in cardiovascular and respiratory diseases, as well as an increase in mortality from them (Hajat et al., 2010). Experts of the World Health Organization (WHO) noted that up to 80 % of diseases now have a natural origin as a result of environmental changes. According to the opinion of the world scientific community, formulated at the end of the last century at the international forum in Rio de Janeiro, the global problem of humanity in the third millennium will be the problem of preserving human life and health in conditions of environmental deterioration (Prüss-

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Üstün, Corvalan, 2006). Hydromineral resources are an important component of the natural recreational potential of mountain areas in various countries of the world. One of these territories is the Carpathian region of Ukraine, which covers part of the mountain system of the same name, as well as the Precarpathian highland plain and the Transcarpathian hilly lowland. The physical and geographical features of this region of Ukraine provide conditions for year-round recreational and tourist activities. The various natural and landscape complexes of the Carpathian region of Ukraine are favorable for the development of medical rehabilitation, sport, educational and other types of recreational and tourist activities. Despite the high natural and recreational potential of this territory, the extent of its development is still very small. Bioclimatic and hydromineral resources occupy a special place among the components of the natural recreational potential, therefore the purpose of the work is to assess their features.

The purpose of the study is to determine the possible positive and negative effects of various climatic factors and their dynamics based on the RCP4.5 climate change scenario (the trajectory of changes in the average level of greenhouse gases concentration), as well as the assessment of the hydromineral component of the natural recreational potential in the Carpathian region of Ukraine.

To achieve the goal, the following tasks were formulated and solved: there were determined the possible positive and negative effects of various climatic factors and their dynamics in the mountainous and foothill areas of the region in different seasons of the year; there were characterized the hydromineral resources of certain areas of the Carpathian region of Ukraine.

The object of the study is the natural recreational potential of the Carpathian region of Ukraine, and the subject of the study is the bioclimatic conditions and hydromineral resources of this region.

2. Materials and Methods

The bioclimatic component of the natural recreational potential of the Carpathian region of Ukraine determines the comfort (discomfort) of a person's feeling and well-being, therefore it is important to identify the possible positive and negative effects of various climatic factors and their dynamics in mountain and foothill areas during different seasons of the year. The bioclimatic component of the natural recreational potential is evaluated from the point of view of the comfort of the climatic conditions for the body of a healthy person. The work is based on the results of modeling the average daily values of air temperature (t), wind speed (v) and relative humidity (f) under the RCP4.5 scenario (the trajectory of changes in the average level of greenhouse gases concentration) from 2021 to 2050 and data from the Climate cadastre of Ukraine (1961-1990) at three stations (Dolyna, Rava-Ruska, Uzhhorod) in the foothills area.

There was conducted a study of the possible bioclimatic potential of the Carpathian region of Ukraine and the trend of its dynamics until 2050.

To identify bioclimatic features, complex indicators are most often used, which characterize the thermal state of a person, and take into account the influence of a set of meteorological factors on human body. These indicators make it possible to assess the bioclimatic resources of specific territories, determine their recreational potential, and solve a number of tasks related to the optimization of the influence of climatic conditions on humans. These indicators include: equivalent effective temperature (EET), weather severity indicators (S), reduced temperature value (T_g), facial skin temperature (θ), conventional temperature (T_c) or Arnoldi index, indices of climate sentimentality – Gorchynskyi (K_g) and Khromov (K_h), which are widely used in the assessment of bioclimatic conditions (Katerusha, 2011). With the help of EET, which is a function of temperature, air humidity, as well as wind speed, it is possible to estimate the thermal sensation of a clothed person in the shade. It is calculated by Missenard's equation:

$$EET = 37 - [(37 - t) / (0.68 - 0.0014f + 1/(1.76 + 1.4v^{0,75}))] - 0.29t(1 - f/100), \quad (1)$$

where t is the air temperature, °C; v is the wind speed, m/s; f is the relative humidity, %.

This bioclimatic indicator can be used both when assessing heat load and under cold conditions.

To assess the severity of the weather – a factor that limits a person's stay in the open air and determines the need for appropriate clothing – a large number of indicators of the influence of meteorological variables on the human body have been developed. One of the most common methods for assessing weather severity is the Bodman's (S) method, which is determined by the equation:

$$S = (1 - 0.04t)(1 + 0,272v). \quad (2)$$

To assess the degree of discomfort of various types of urban buildings and their remedial potential depending on the thermal and wind regime of the cold half-year, the method of reduced temperatures (T_g) is used, which is understood as the air temperature at calm. The value of the reduced temperature is determined by the empirical equation:

$$T_g = t - 8.2\, v^{0,5}. \quad (3)$$

In conditions of low temperatures, a person's face and limbs often limit his stay in the open air. Depending on the air temperature and wind speed, the temperature of the skin of the face (θ) is calculated according to the equation:

$$\theta = 0.4t - 3.3\, v^{0,5} + 17. \quad (4)$$

Indicators of severity (harshness) of the weather also include the conventional temperature (T_c) or the Arnold's index. This indicator is calculated according to the equation:

$$T_c = t - 2v\ . \quad (5)$$

There is a clear relationship between increasing weather harshness and decreasing cheek skin temperature in people who work outdoors in winter. The decrease in the skin temperature of the cheek is proportional to the decrease in the conditioned temperature (T_c).

To assess the continentality of the climate, the Gorchynskyi (K_g) and Khromov (K_h) indices are most often used:

$$K_g = (1.7A\ /\sin\varphi) - 20.4 \ \ (\text{for } \varphi = 30\text{–}60°), \quad (6)$$

$$K_h = [(A - 5.4\sin\varphi)\ /A]\cdot 100\ , \quad (7)$$

where A is the annual amplitude of air temperature; φ is the width.

The characteristics of hydromineral resources are given according to the data of the Ukrainian Research Institute of Medical Rehabilitation and Resort Therapy of the Ministry of Health of Ukraine.

3. Results and Discussion

Currently existing climate forecasts for certain-scenarios are usually presented in the form of basic climate indicators of individual meteorological parameters. However, consumers need a specialized forecast, i.e., specialized climate properties. Thus, on the basis of the predicted basic characteristics under a certain scenario, it is possible to proceed to the forecast of the necessary special characteristics (Agency for Rational Use of Energy and Ecology, 1998).

The results of the research showed that comfortable conditions for EET at all stations are possible from April to October (with a maximum in summer). Moreover, they are most likely to be observed in Uzhhorod (up to 78,4 % in July), i.e., bioclimate conditions for human life and recreation will be most favorable (high bioclimatic potential). In the Precarpathian Highlands, “very cold” and “cold” conditions are most common (36.1–50.3 %) in winter, in the Transcarpathian Lowlands “cold” conditions prevail (recurrence 23.6–53.4 %), but the risk of frostbite is also possible. The greatest increase in calculated *EET* values relative to the climatic norm is expected in Rava-Ruska and Dolyna in the cold period of the year: up to 2.8 °C (January) and 1.1 °C (February), respectively. In Transcarpathia, the *EET* will decrease from October to June, and will increase by 0.3 to 0.9 °C in the rest of the months. Precarpathia is expected to have mostly moderately severe winters, while Transcarpathia is expected to have slightly severe winters with a frequency above 50 % and above 60 %, respectively (according to the values of the Bodman's index). The temperature of the face skin in the winter period can quite often fall below the threshold of discomfort – 10 ºC, which limits the time a person can spend outdoors, due to blood circulatory disorder in the tissues of the external areas of human body. In some cases, it will drop even below 4 ºC, i.e., it may cause a tissue frostbite (beginning of hypothermia). The values of the “harshness of the weather” coefficient according to Arnoldi clearly correlate with human physiology. With a repeatability of ≥80 %, a weak tension of the thermoregulation apparatus is expected. This indicator makes possible to determine the needs of a clothed person, which provides the person with thermal comfort when working outdoors. The values of the possible reduced temperature indicate that in Uzhhorod and Rava-Ruska with a recurrence of ≥70 % and ≥50 %, respectively, there are no restrictions for people to stay outdoors. In Dolyna, in majority of cases it is necessary for weakened people or people with disorders of the cardiovascular system to partially limit spending their time outdoors. Index of climate continentality according to Gorchynskyi (K_g) in the foothills of the Carpathians in 1961–1990 was ≤31 %, i.e., the climate here is transitional. This index is expected to decrease to 29 % in 2021–2050. Climate continentality index according to Khromov (K_h), which shows the continental contribution to the annual air temperature amplitude, will decrease from 82 % to 81 %.

The considered possible complex bioclimatic indices will allow to form conditions and prospects for improving the quality of life and human safety.

EET in the foothills of the Ukrainian Carpathians will, on average, increase over the year relative to the climatic norm, while in Transcarpathia it will decrease. However, in the warm period of the year, its growth is expected mainly in the entire region, which will lead to the improvement of recreation conditions and will be able to attract a larger number of recreationists. The values of the expected bioclimatic indicators in average for the winter will remain within the same limits as the climatic norm, although their anomalies can be both negative and positive. Therefore, with the development of this scenario of climatic changes, a significant deterioration of the conditions of winter types of recreational and tourist activities is not predicted.

The main ski centers of the Carpathian region of Ukraine are located on the territory of the mountain ranges.

Unfortunately, there are no data directly on these points, but the trend of decreasing seasonal winter air temperatures observed in the foothills will be observed more clearly in high mountain areas, which is a positive factor for the preservation and development of winter forms of recreational and tourist activities in the Ukrainian Carpathians until 2050. It is unlikely that, even with the development of the RCP8.5 scenario (maximum emission of greenhouse gases), the increase in air temperature in the winter periods in the Ukrainian Carpathians will significantly affect the forecast deterioration of the conditions of winter forms of recreational and tourist activities (Safranov, Khokhlov, & Volkov, 2016). Data on bioclimatic resources provide an opportunity to adapt by increasing the productivity of various sectors of the economy, with improved outcomes for the environment, health and well-being of people in this recreation area.

The peculiarities of the geological and hydrogeological conditions of the Ukrainian Carpathians were reflected in the diversity of the chemical composition of underground waters and the specificity of the mineral therapeutic waters used in the popular balneological resorts of Precarpathia and Transcarpathia, although in other parts of the region there are also various mineral healing waters that can be used for balneological purposes. The properties of mineral healing waters of four national natural parks of the Ukrainian Carpathians were analyzed, which, in combination with other natural recreational resources, will contribute to the creation of spa resort facilities (sanatoria), medical and social-psychological rehabilitation centers (Novodran et al., 2013).

On the territory of Synevyr National Nature Park, cold healing mineral waters of different mineralization and chemical composition were discovered. There are lightly mineralized (up to 0.39 g/dm^3) waters of HCO_3^-, SO_4^{2-}–$HCO_3^-Na^+$, Ca^{2+}–Na^+ without specific components and properties. Water-soluble gases are represented by O_2, CO_2 and H_2S. In the group of carbonated waters, lightly mineralized (0.86 g/dm^3) $HCO_3^-Na^+$ and more mineralized (3.54–3.95 g/dm^3) Cl^-–$HCO_3^-Ca^{2+}$–Na^+ are distinguished. The content of CO_2 varies from 1.34 to 2.25 g/dm^3. Water-soluble gases include H_2S (0.24–1.75 mg/dm^3). In addition, in one of the sources (the village of Kolochava), the content of *Fe* reaches 10.5 mg/dm^3, H_3BO_3–39.0 mg/dm^3, which makes it possible to classify it as ferruginous boric waters. Carbonated waters contain NH_4^+ ions, which is typical for this type of mineral healing water. No radioactive components were detected. The waters of this national natural park meet the chemical and sanitary requirements for the regulated components and are perspective for practical use (Kolesnyk, Babov, 2005). Several types of healing mineral waters were found on the territory of Vyzhnytskyi National Nature Park (Babov et al., 2012). The specific properties of lightly mineralized (up to 1.0 g/dm^3) mineral waters (MW) are due to the increased content of C_{org} (up to 30 mg/dm^3). These waters with flow rates of 3.4–17.2 m^3/day were discovered with wells in Cretaceous and Paleogene sediments at depths of 50–125 m. They contain HCO_3^-, SO_4^2- and Cl^-–HCO_3^-, Na^+, Ca^{2+}– Na^+. Increased concentrations of C_{org} (5.0–10.8 mg/dm^3) SO_4^{2-}, Cl^- and HCO_3^-– SO_4^{2-} complex cationic composition are characteristic of spring water of the Luzhky tract. The water from well No. 32M is medicinal and suitable for bottling, and can be used in the treatment of certain diseases of the liver, kidneys, metabolic disorders, etc. It has SO_4^{2-}– $HCO_3^-Mg^{2+}$–Ca^{2+} composition and mineralization of 0.6 g/dm^3; content C_{org} is 6.2–9.6 mg/dm^3. Among lightly mineralized waters (0.6 g/dm^3) of HCO_3^-– Ca^{2+}, Mg^{2+}–Ca^{2+} composition, the source "Diana" is the most studied; the conten of C_{org} varies from 8.1 to 14.2 mg/dm^3. After conducting modern researches, the use of water may be recommended for the treatment of some diseases of the liver, kidneys, and metabolic disorders. On the territory of the national nature park, several more sources of MW were discovered, among which the source "Byk" can be noted, which has a $HCO_3^-Mg^{2+}$– Ca^{2+} composition and a mineralization of 0.44 g/dm^3. It is used by the local population for drinking purposes, but the high content of C_{org}

(8.9 mg/dm^3) suggests its biological activity and medicinal properties. MW of low mineralization (1.0–5.0 g/dm^3) of different chemical composition was revealed by wells on the territory of the NNP in Cretaceous and Paleogene sediments at depths from 30 to 150 with mineralization from 2,4 to 3.9 g/dm^3. By chemical composition, they are Cl^-–HCO_3 and HCO_3^-–Cl^-Na^+. Concentrations of Standardized components (*Pb*, *Cr*, *F*, etc.) do not exceed the threshold limit value (TLV). MW of medium mineralization (8.6 g/dm^3) HCO_3^-–Cl^-Na^+ composition, cold, lightly alkaline (pH=7.8) was discovered only by one well in Paleogene sediments. Concentrations of biologically active substances are lower than balneological norms, and their standardized components are below the maximum permissible concentrations. The flow rate of the well is very low (1.7 m^3/d). MW of high mineralization (10–35 g/dm^3), Cl^-Na^+ composition, lightly alkaline (pH=7.7) were discovered by wells in Oligocene sediments at depths of 25–125 m. Among the components that determine the sanitary and chemical state of water, there are ions NH_4^+ (3–15 mg/dm^3). These waters are recommended for use in baths, showers, etc. Salts with mineralization over 35 g/dm^3 were discovered by wells in Oligocene sediments at depths of 30–100 m. They are characterized by increased concentrations of NH_4^+ ions (10–36 mg/dm^3). In mineral waters with increased content of biologically active components and compounds, such components as *B*r, *Fe* and *B* were detected. When diluted, they can be used as bromine water for internal use, despite the low flow rates of both wells. Of interest is the brine (117.81 g/dm^3) Cl^-Na^+ composition of the Chereshenka spring from a mine well 25 m deep in Neogene sediments with a flow rate of 50 m^3/d. It contains 163.84 mg/dm^3 Br and 4.6 mg/dm^3 J, i.e, it can be classified as bromine and even iodo-bromine brines. The concentration of standardized components does not exceed the maximum permissible values. Mineral waters of this type are usually used in diluted form for external (15–35 g/dm^3) and internal (3–15 g/dm^3) use. Within the boundaries of this national nature park is the spring "Luzhky" SO_4^{2-}, Cl^-–$SO_4^{2-}Mg^{2+}$–Na^+ with mineralization of 0.3–0.41 g/dm^3. This water is characterized by an increased content of *Fe* (14 mg/dm^3) and H_2SiO_3 (77.92 mg/dm^3). The content of *Mn* is 1.1 mg/dm^3, Al – 10 mg/dm^3. It belongs to ferrous siliceous lightly mineralized SO_4^{2-}, Cl^-–$SO_4^{2-}Mg^{2+}$–Na^+ and has complex cation composition.

The waters of the National Nature Park "Skolivski Beskydy" are characterized as lightly mineralized without specific components and properties, iodine-bromine, sulphide, with an increased content of organic substances. They have mineralization from 0.12 to 0.99 g/dm^3, pH value from 6.6 to 9.0. CO_2 and O_2, as well as H_2S (0.36-0.58 mg/dm^3) are present in the composition of WSG. Water of HCO_3–, sometimes SO_4^{2-}–$HCO_3^-Na^+$–Ca^2 composition. The sanitary-chemical state of these waters is satisfactory. Biologically active components (*J*, *Br*, *Rn*, *Fe*, *Si*, *B*, C_{org}) are present in concentrations below balneological norms. The content of *Pb*, *Cd*, *As*, *Zn*, *Cu*, *V*, *Cr*, *Sr*, *F* is below the maximum permissible concentration values. Water contains high concentrations of *Ra*, which can be a precursor to the presence of *Rn*, which can enhance the healing properties of water. Iodine- bromine, chloride, and sodium brines of the "Ropa" spring have been used for medicinal purposes since ancient times. In the water-soluble gases of the source of low-sulphide waters (the village of Pereprosten), in addition to H_2S (10.3 mg/dm^3), there is also CO_2 (23.8 mg/dm^3). These water sare promising for sanatorium-resort use (Kolesnyk, Babov, 2005).

Groundwaters in the territory of the Yavorivskyi National Nature Park can be classified as lightly mineralized (0.35–0.68 g/dm^3) waters without specific components and properties (Mineral Waters of Ukraine, 2005). Water-soluble gases include CO_2 (7.8–14.4 mg/dm^3) and O_2 (3.0–6.2 mg/dm^3). The chemical composition of water is $HCO_3^-Ca^{2+}$ and $HCO_3^-Ca^{2+}$–Na^+. The sanitary and chemical state of the water is satisfactory. Biologically active components (*J*, *Br*, *Rn*, *Fe*, C_{org}) in the waters are present in concentrations below balneological norms. Concentrations of *As*, *Pb*, *Se*, *Cu*, *Zn*, *V*, *Cr*, *Hg*, *Sr*, *U*, *Ra*, *F* and other standardized components in groundwater are significantly lower than the maximum permissible concentrations.

4. Conclusion

Thus, favorable bioclimatic conditions, the presence of mineral healing waters, as well as other components of the natural recreational potential (peloids, ozokerite, unique forest ecosystems, various natural landscape complexes, etc.) will contribute to the development of sustainable recreational, tourist and health activities within the Carpathian region of Ukraine.

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