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Mountain Tourist Destination – the Quality of Groundwater Sources

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ABSTRACT

The Carpathian region is distinguished by a high tourist flow and variety of hotels. The need for consumption of quality drinking water for tourists and local population is determined. Underground sources and wells constitute a water supply of accommodation facilities in this region. The issue of drinking water quality in the Carpathians remains poorly studied. It is necessary to realize the landscape, the content of heavy metals in the rocks, the differences in elevation, and tourist flow that can cause diffusion pollution. Sources of water supply in the tourist area of the Ukrainian Carpathians are the subject of the article. The sociological survey of the owners of local tourist accommodation facilities showed that 17.5% use surface sources, 48.8% use underground sources, 32.5% use mixed sources, 56.2% of respondents dispose of sewage disposal without proper water reclamation. We took samples of drinking water from sources, wells in this region and analyzed such indicators as pH, temperature, altitude, nitrates and nitrites, phosphates, ammonium, and mineralization. Sensafe's visual membrane tests for drinking water determined heavy metals such as Cu, Ni, Co, Zn, Cd, Hg, Fe in the water samples. The functional dependence of the content of heavy metals and the altitude zonation of drinking water sources for the region ***is*** described by the equation $y = -0.059\ln(x) + 0.4219$.

Keywords: groundwater, seasonal fluctuations, physical and chemical composition, spring water, nitrates, heavy metals, Carpathian tourist region.

INTRODUCTION

Carpathian tourist region is characterized by a large number of tourist accommodation facilities and high rates of tourist flows. These factors predetermine the need to consume quality drinking water for tourists and local population [Mandryk et al., 2020]. Underground sources, wells, and boreholes play a significant role in the region's drinking water supply, as well as the water supply of many accommodation facilities [Kravchynskyi et al., 2021]. On the other hand, tourist destinations, especially mountainous ones, cause significant anthropogenic pressure on the environment, in particular, on the quality of natural waters resources [Pobihun et al., 2019]. In addition, there is a lack of centralized water supply, forcing site owners to rely on wells and boreholes or neighboring drinking water sources [Korchemlyuk et al., 2019]. Accordingly, there is a vast number of unstudied water sources [Arkhypova and Pernerovska, 2015]. We established the examined region based on the preliminary survey, feedback from the local population and owners of tourist lodging businesses about the state of drinking water. According to the results of the anonymous survey, most respondents pointed to certain problems and cited various factors that affect the quality of drinking spring water. The obtained results demanded the collection and analysis of spring water samples from the mountain tourist area.

More than 1 million travelers visit the Yaremchean tourist destination annually. Therefore we have chosen this region for the experimental research [Korchemlyuk and Arkhypova, 2016]. The issue of the quality of drinking water in this area's underground springs and wells remains relevant and understudied, because it is necessary to take into account the specifics of the mountainous landscape, the content of heavy metals in the rock, the presence of significant elevation differences, and a significant tourist load [Stevens et al., 2011]. A significant contribution to the study of drinking water sources of the Carpathian region made Kravchinsky R.L., Khilchevsky V. K., Korchemlyuk M.V., Stefurak A.M. in their monograph on the monitoring of drinking water sources of the Carpathian NPP [Kravchynskyi et al., 2019]. Cherega A.M., V.A. Ishchenko [Cherneha and Ishchenko, 2016] carefully researched the composition of drinking water from decentralized water supply sources.

MATERIALS AND METHODS

The study's subject is water from natural springs, wells, and sources in the Carpathian tourist destination. The altitude zonality of the sources had an essential impact in the selection of water sampling locations for the investigation [Odnorih et al., 2020]. We conducted a sociological study of the owners of local tourist accommodations and showed the necessity for monitoring and analysis of the Carpathian tourist destination. We analysed samples of drinking water from springs, wells, and sources in the region using the following indicators: pH, temperature, altitude, nitrates and nitrites, phosphates, ammonium, and mineralization [Malovanyy et al., 2019]. Sensafe visual membrane tests for drinking water were used to assess the presence of heavy metals in water samples, such as: Cu, Ni, Co, Zn, Cd, Hg, Fe [Korchemliuk et al., 2013]. According to the instructions, we used the following portable devices and reagents for operational monitoring:

- Ph-meter, conductometer, salt meter, oximeter - AZ-86031;
- GPS-tracker – GPSmap 60Cx;
- visual tests of nitrates and nitrites, phosphates and ammonium – Ptero;
- visual membrane tests for determination of heavy metals – Sensafe.

To determine the physical and chemical properties of water we used physical, organoleptic, potentiometric, titrimetric, and photometric approaches in field and laboratory research [Gomelia et al., 2018]. Dsanpin 2.2.4-171-10 [DSanPiN, 2021] was used as the principal normative document (ND) controlling the qualitative and quantitative indicators [DSanPiN, 2021]. In general, the structure of a water source monitoring system includes the sequential implementation of the following stages:

1) Information acquisition – data mining;
2) Field measurements at the first level – mapping;
3) Field measurements at the second level – sampling;
4) Field measurements at the third level – monitoring.

PRESENTATION OF THE FUNDAMENTAL MATERIAL

Sociological survey

In analyzed mountainous region, there is a substantial concentration of tourist lodging facilities. The data of the accommodation services website showed the amount of registered establishments providing services for temporary lodging of travelers is around 1,000 [Karpaty info, 2021]. We conducted a sociological survey was undertaken, with around 100 respondents-owners of tourist lodging facilities interviewed. The survey is based on the results of a preliminary assessment of the region on the accumulation of private estates and hotels.

According to the respondents' responses, the advantage of utilizing decentralized water supply is 62.5% in the region under research, while mixed water supply is 32.5%. The analysis found that wells and boreholes account for 77.5% of decentralized water supply, while springs account for 22.5%. The reference of respondents to the signs of pollution (color, turbidity, sediment, and odor) of water for consumption was an essential indicator for the study, 37.5% of respondents saw

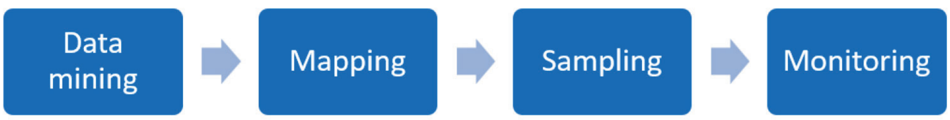

Figure 1. Structure of the source and well monitoring system

Table 1. The findings of a sociological study on the consumption of groundwater and springs by owners of tourist accommodation facilities

No.	Survey item	Number of respondents' answers, %
1	Owners of tourist accommodations	86.2
2	Decentralized water supply	62.5
3	Mixed water supply	32.5
4	Ground water use	48.8
5	Spring water consumption for drinking purposes	63.7
6	Use of wells, springs, wells	77.5
7	Spring use with natural leakage	22.5
8	Sightings of contamination of drinking water	37.5
9	Use of filtered drinking water	26.3

indicators of pollution and reported water deterioration throughout the flood season (Table 1).

The research on indicators of drinking water contamination is being questioned, because water source monitoring is only done in the case of an emergency report or when there are indications from local residents.

Research of drinking water sources and wells

The sites of monitoring of the state of the quality of drainage water, boreholes, and wells we established on the basis of a sociological survey, analyzed the scientific research on the reverse region [Kneysler et al., 2020; Mandryk et al., 2017; Kinash et al., 2019; Komlev et al., 2021], and conducted the field exploration. In each of the monitoring points shown in Figure 2, we took the water samples according to the current ND. We determined GPS-coordinates and altitude above sea level and mapped sampling points. We analized the samples on-site using AZ-86031 organoleptic indicators, temperature, salinity and acidity.

We obtained physico-chemical parameters of spring water by laboratory and field research, which we processed and published in tables 3,4. We made sampling on April 7, 2021, during the hydrological season of spring flood. The pH of drinking spring water must be 6.5–8.5 pH units, according to DSanPiN 2.2.4-171-10. In contrast to the received data, we can see that only two samples with more sour environment indicator 5,58 and alkaline 10,34 exceeded the norms, indicating the need for additional research to determine the sources of the influence on pH indicator. The pH indicator in all other samples is within a defined range. Ammonium ions in the investigated samples are within the norm, while nitrite and phosphate levels are also within safe limits. Heavy metals (HM) are one of the most dangerous components of pollution [Yatsyshyn et al., 2020]. For spring water and wells, as well as indications of VM content, monitoring of water bodies is sufficient. Special emphasis is devoted to elements with a valence of +2 in the mountainous region, such as Fe and Cu, because the rocks in this area are rich in compounds of these metals, and their concentration is dependent on declining forest cover. Thus, we observe the heavy metal leaching from rocks and their impregnation in springs and wells.

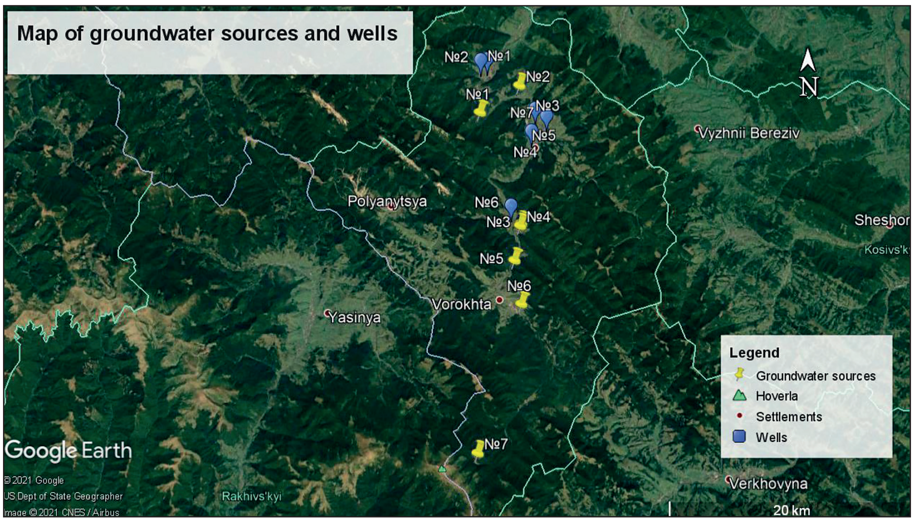

Figure 2. Location of studied natural sources of drinking water, wells and boreholes

The content of Fe and Cu in samples is insignificant, but the total metal content such as: copper, iron, cobalt, zinc, cadmium, lead, nickel, mercury, manganese and other metals with valence +2 are illustrated in three samples derived from natural drinking water sources (Table 2, 3). When compared to natural sources, there is no considerable contamination from wells and boreholes. We identified an excess of nitrates in various samples of water from wells and sources, specifically in samples No. 4, No. 5 and No. 7. Fe and Cu content in samples was not significantly increased. Copper, iron, cobalt, zinc, cadmium, lead, nickel, mercury, manganese, and other metals with valence +2 are represented in four samples taken from wells and sources (Table 4, 5).

Water type by salinity in the analyzed wells and source is normal-nonsaline with a salinity index of 100–500 mg/l. In the springs in the sample number 1 – normally fresh water, in samples number 2, 6 – the most mineral with an indicator in the range 10–30 mg/l, all other samples of spring water – very fresh water with an indicator in the range 30–100 mg/l (Table 6).

Integrated analyses of water quality using hydrochemical indicators provide more objective information for environmental reasons [Khilchevskyi et al., 2012]. The term "water pollution index" (pv) refers to a group of indicators that are commonly used to measure the quality of bodies of water. This index is a typical additive coefficient that represents the average proportion of specific ingredients that surpass the MPC:

$$\mathrm{IWP} = \frac{1}{n}\sum_{i=1}^{n}\frac{C_c}{\mathrm{MPC_i}} \quad (1)$$

where: C_c – component concentration (in some cases – value of physico-chemical parameter,
n – number of indicators used to calculate the index,
$\mathrm{MPC_i}$ – established value of maximum permissible concentration of i – component with corresponding type of water body.

Table 2. The results of research on the indicators of heavy metals of natural sources of the Carpathian National Nature Park. April 7, 2021 / Spring flood

Sample number	Coordinates	Altitude, m.	Iron (Fe^{2+}), mg/dm³	A mixture of metals (Cu, Ni, Co, Zn, Cd, Hg) mg/dm³	Cu, mg/dm³
1	N48024'42.1" E024032'16.6"	536.0	0.02	0.10	0.05
2	N48025'52.5" E024034'52.5"	564.0	0.02	0.05	0.02
3	N48019'51" E024034'59.6"	718.0	0.01	<0.01	0.02
4	N48019'45.3" E024034'55.4"	692.0	0.01	0.01	0.01
5	N48018'14.9" E024034'32.9"	731.0	0.02	0.02	0.02
6	N48016'20.5" E024035'0.08"	779.0	0.02	0.01	0.01
7	N4809'49.6" E024032'8.3"	1500.0	0.00	0.01	0.01

Table 3. The results of research on the physical and chemical composition of natural sources of the Carpathian National Nature Park. April 7, 2021 / Spring flood

Sample number	Temperature, °C	pH	Ammonium ion, mg/dm³	Nitrite ion, mg/dm³	Nitrate ion, mg/dm³	Phosphate, mg/dm³	Mineralization,mg/dm³
1	8.50	10.15	0.25	0.20	1.2	0.250	352
2	9.30	8.35	0.25	0.15	1.6	0.050	29
3	8.00	7.46	0.25	0.00	1.8	0.01	63
4	7.50	7.47	0.25	0.00	1.4	0.05	54
5	7.50	7.60	0.25	0.00	1.5	0.02	38
6	7.00	7.00	0.25	0.00	0.9	0.01	25
7	7.00	7.60	0.00	0.00	0.3	0.05	66

Table 4. The results of research on the indicators of heavy metals of wells on the territory of tourist estates within the Yaremche tourist destination. April 7, 2021 / Spring flood

Sample number	Place of sampling	Altitude, m. Coordinates	Iron (Fe^{2+}), mg/dm³	A mixture of metals (Cu, Ni, Co, Zn, Cd, Hg) mg/dm³	Cu, mg/dm³
1	A well near the CNNP office	540 m, N48026'44.4" E024032'57.5"	0.02	0.10	0.05
2	Yaremche, Daniv, well	533 m, N48026'41.8" E024032'31.7"	0.02	0.07	0.05
3	Mykulychyn, "Nota bene", Kiselyuk, well	580 m, N48024'34.2" E024036'06.8"	0.02	0.10	0.04
4	Mykulychyn, "Nadiya and P", Popovych, well	595 m, N48023'36.2" E024035'52.1"	0.02	0.02	0.05
5	Mykulychyn, "Nadiya and P", Popovych, well 2	595 m, N48023'36.2" E024035'52.1"	0.02	0.02	0.04
6	Tatariv, Novak, well	686 m, N48020'21.0" E024034'31.8"	0.02	0.07	0.03
7	Mykulychyn "Cozy Nest", Savchuk, well	593 m, N48024'15.7" E024036'52.0"	0.02	0.02	0.01

Table 5. The results of research on the physical and chemical composition of wells on the territory of tourist estates within the Yaremche tourist destination. April 7, 2021 / Spring flood

Sample number	Temperature, °C	pH	Ammonium ion, mg/dm³	Nitrite ion, mg/dm³	Nitrate ion, mg/dm³	Phosphate, mg/dm³	Mineralization, mg/dm³
1	8.80	7.90	0.70	0.15	0.50	0.000	105
2	6.70	10.34	0.25	0.10	2.10	0.250	189
3	9.90	7.29	0.35	0.15	2.7	0.1	331
4	11.60	6.80	0.25	0.18	5.3	0.05	334
5	11.80	6.62	0.90	0.15	6.3	0.05	270
6	9.00	5.58	0.25	0.00	0	0.05	166
7	9.10	6.92	0.25	0.00	5.9	0	223

Table 6. Distribution of the studied natural sources and wells Yaremche tourist destination by salinity (mg/dm³)

Water type by salinity	Maneralization, mg/dm3	Number of sources	Number of wells and sources
Superleaves	<10	0	0
The freshest	10–30	2	0
Very fresh	30–100	4	0
Normally fresh	100–500	1	7
Fresh	500–1000	0	0
Lightly salted	1000–3000	0	0

Depending on the from, water is evaluated by classes (Table 7). The IWP was determined using six indicators such as ammonium ion, nitrate ion, phosphates, iron, the average of the sum of metals (copper, iron, cobalt, zinc, cadmium, lead, nickel, mercury, manganese and other metals with valence +2), iron and copper separately (Table 8). The investigation indicated a pattern of VM leaching from rocks, with the vast majority of spring water samples containing a high quantity of VMs collected at altitudes ranging from 500 to 800 meters above

Table 7. Drinking water quality classes according to IWP indicator

Water quality classes	IWP value
I – very clear	< 0.3
II – clear	0.3 < I3B <1
III – moderately polluted	1 < I3B < 2.5
IV – polluted	2.5 < I3B < 4
V – dirty	4 < I3B < 6
VI – very dirty	6 < I3B < 10
VII – extremely dirty	> 10

Table 8. Water quality class assignment based on IWP parameter in examined water samples from springs and wells

Number of the sample	Location of the water source	IWP	Characteristics of water quality	Drinking water quality classes
Nature springs				
1	Yaremchan Pondv, near the hotel	0.26	Very clear	I
2	Yamna, by the road	0.29	Very clear	I
3	Pigi	0.30	Very clear	I
4	Pidgrebyn	0.25	Very clear	I
5	Vorokhta, s/he «Rebrovach».	0.26	Very clear	I
6	Vorokhta, Vorokhtyany OPDV	0.17	Very clear	I
7	Goverlyany OAP	0.05	Very clear	I
Wells and sources				
1	The well near the PNC office	0.20	Very clear	I
2	Yaremche, Danov, well	0.40	Clear	II
3	Mikulichyn, «Nota bene», Kiselyuk, well	0.48	Clear	II
4	Mikulichyn, «Nadiya and P», Popovic, well	0.82	Clear	II
5	Mikulichyn, «Hope and P», Popovich, well	1.06	Moderately polluted	III
6	Tataryv, Novak, well	0.06	Very clear	I
7	Mikulichyn «Cozy Nest», Savchuk, well	0.90	Clear	II

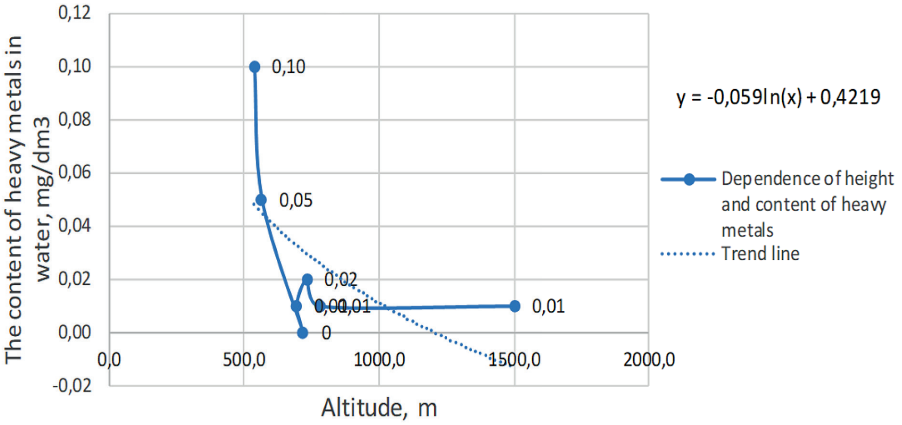

Figure 3. Dependence of height and content of heavy metals

sea level. We established the tendency for pollution to rise with decreasing altitude using a trend line based on the results and their ratio (Figure 3). This link applies solely to sources in the research region, not to wells and springs.

CONCLUSIONS

We obtained information from the study on the mountain tourist destination, analyzed tourist flows and the number of tourist accommodation facilities, and devised and conducted a sociological survey on the basis of this information. Then, our sociological survey established the relevance of additional investigation of the region's water sources and wells. We explored and mapped the most used water sources and wells. Also, we conducted field study, taking samples and describing natural springs and wells near tourist farmsteads. We compared the principal indicators to the maximum allowable values. Heavy metal content in samples was found to be altitude dependent. We began monitoring subsurface sources for further investigation and control.

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