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AGROECOLOGICAL MONITORING OF WATER ECOSYSTEMS AND SOILS IN THE BASIN OF A SMALL RIVER UNDER THE INFLUENCE OF ANTHROPOGENIC FACTORS

SUMMARY

In the contemporary socio–ecological–economic life of Ukraine, rural areas hold a special place – they are an integral part of the agro–sphere, as more than a third of the population of our country lives there. These areas are characterized by an exceptional contribution to the formation of the foundations of food security. Increasing the country's export potential makes the development of rural areas one of the main priorities of Ukraine's state policy, aimed at raising the living standards of the rural population, improving the efficiency of the agro–industrial complex (AIC), enhancing the state of the environment, and improving the quality of life of villagers. However, the monitoring of agricultural lands is conducted at the state level, while residential areas where the population grows products for their own needs are rarely studied, and according to the population itself, the norms for the use of chemical protection agents and fertilizers are not always followed. Many settlements in Ukraine with traditional agriculture are located near rivers within watersheds. A modern environmental assessment of rural residential areas located in the basins of small rivers remains relevant, unimplemented, and requires regular research, socio–ecological monitoring, and scientific justification for their ecologically balanced development. One of the important environmental issues is the chemical pollution of water ecosystems in the basin of a small river due to anthropogenic impact. Uncontrolled discharge of wastewater from urban treatment facilities leads to chemical pollution of surface waters within the settlement of Tlumach. The soils of residential areas located

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within watershed basins also experience significant anthropogenic pressure. Agroecological monitoring has been conducted to determine biogenic elements, salt composition, content of trace elements and heavy metals in surface and groundwater, as well as the physico–chemical and agrochemical composition of soils in residential areas within the watershed basin of the Tlumachik River.

Keywords: anthropogenic load, monitoring, surface waters, soil, heavy metals, residential areas.

INTRODUCTION

The issues of environmental safety are relevant for the Western region of Ukraine and are determined by a specific combination of natural, socio–economic, and other factors. Uncontrolled anthropogenic load leads to degradation of agro–landscape, negatively impacting soils, biodiversity, the quality of surface and groundwater, as well as reducing the productivity of agro–ecosystems. (Wilson, 2010; Kanianska, 2016; Litvinova *et al*., 2023a; Litvinova *et al.*, 2023b). Anthropogenic pressure affects the redistribution of elements and substances in the biosphere, leading to the accumulation of their toxic derivatives such as organic substances, phenols, nitrogen and phosphorus compounds, heavy metals in agro–landscapes, particularly in soils and natural waters. The ecological balance between natural and anthropogenically altered landscapes, due to economic activities, is disrupted (Korsun and Palapa, 2014; Palapa *et al.*, 2017; Sasakova *et al.,* 2018; Radchenko *et al.*, 2024a). In the Western region of Ukraine, the main factors influencing environmental safety include: relatively high population density and dense urbanization, waste accumulation, degradation processes linked to both climatic conditions and anthropogenic factors, and outdated and imperfect production technologies, among others (Litvinova *et al.*, 2021). The situation with water supply, drainage, and the quality of drinking water in rural areas is complex. In the regional centers of the Western region, groundwater, surface water, or mixed water sources are used for water supply (Pavlichenko *et al*., 2023; Voitovyk *et al.,* 2023; Havryliuk *et al.,* 2024).

Ukraine is one of the least water–secure countries in Europe, yet water use in the country is predominantly irrational. As a result of toxic, microbiological, and biogenic pollution, the ecological condition of river basins continues to deteriorate steadily (The Law of Ukraine – Document 2697–VIII).

Therefore, continuous monitoring of surface water bodies, implementation of measures for their conservation, restoration, and protection are of utmost importance. Although the region of the Ukrainian Carpathians and adjacent territories are rich in water resources, including river runoff, groundwater, and water in lakes and reservoirs (Prykhodko, 2012), there are many problematic issues related to the environmental safety of these natural sources. Among the main issues are excessive anthropogenic pressure on water bodies due to intensive water management practices, discharge of polluted effluents, leading to increased concentrations of harmful substances in water bodies, and the impact of floods (Kravtsiva, 2013; Andel, 2013). Anthropogenic pressure often leads to the degradation of agro–landscapes, which negatively impacts soils and the quality of surface and groundwater, resulting in the accumulation of organic substances, phenols, nitrogen and phosphorus compounds, as well as heavy metals in them (Wilson, 2010; Kanianska, 2016; Sasakova *et al*., 2018).

The quality of drinking water in centralized and decentralized water supply systems is influenced by the condition of surface water bodies, which serve as water sources (Valerko and Herasymchuk, 2020). The consumption of poor–quality drinking water affects health and leads to increased illnesses in rural populations (Lototska *et al*., 2019). Water quality depends on the geological structure of the land and anthropogenic activities conducted around water bodies, particularly on agricultural waste disposal methods (Mahananda *et al.,* 2010; Davydiuk *et al*., 2020; Shkarivska *et al*., 2021). Overall, the ecological condition of surface waters is influenced by various factors closely related to soil pollution, changes in landscape structure, and disruption of ecologically balanced relationships between fields, meadows, and forests. These factors negatively impact landscape stability, leading to river siltation due to water regime violations in water bodies and land erosion in coastal protection zones (Litvinova *et al*., 2019; Litvinova *et al.*, 2020; Radchenko *et al.*, 2024b).

Other important anthropogenic factors influencing river basins include deforestation, development of degradation processes, land drainage, irrational fertilizer application, improper storage of pesticides in warehouses, creation of artificial reservoirs, canals, channelization of rivers and their tributaries, increased urbanization (settlement) of the basin, and extraction of minerals such as peat, iron ore, oil, and gas (Doroshenko, 2017). One of the sources of surface water pollution is considered to be the private sector, a significant portion of which is not covered by centralized sewage systems, resulting in untreated wastewater being discharged directly into small rivers. Makeshift garbage dumps often appear on the shores of water bodies. The absence of specific land users in nature reserves, the dissolution and fragmentation of collective agricultural enterprises, and their inclusion in the administrative territories of rural and township councils without effective control mechanisms also negatively affect the ecological state of water bodies (Nikolaichuk *et al.,* 2015). Significant challenges to safety and human health arise from water pollution by agricultural enterprises (Jiang *et al.*, 2020).

A critically important issue is the reduction of ecological risk related to the pollution of small rivers (up to 10 km in length, first and second–order streams), which contribute to the flow and water quality of larger rivers. Small rivers are the first and highly vulnerable element (due to their low self–purification potential) of the hydrographic network of a river basin (The Law of Ukraine – Document 2697–VIII). The quality of water in surface water bodies reflects the overall state of the ecosystem. Excessive amounts of harmful substances alter the physico–chemical properties of water, leading to contamination of drinking water sources. Lakes and reservoirs accumulate the highest concentrations of agricultural pollutants. For instance, annually from fields, lakes receive 1554.13 tons of total nitrogen and 1.94 tons of phosphorus, while from meadows, they receive 9.5 tons of nitrogen and 0.20 tons of phosphorus (Česonienė *et al.*, 2021a).

The issue of studying the impact of anthropogenic load on the state of surface waters in the western region of Ukraine is extremely relevant. Equally important are monitoring studies on the condition of naturally sourced drinking water in decentralized water supply systems (wells and pipelines) in rural areas located within river basins. Research on soils within agricultural territories is also crucial, as the population grows and consumes agricultural produce grown there. This necessitates establishing the accumulation patterns of biogenic elements and pollutants within the components of the agro–ecosystem of the Western region of Ukraine in watershed areas.

The aim of the research was to conduct an eco–agrochemical assessment of the state of agricultural landscapes in the western region of Ukraine, including rural areas within the watershed of a small river, and to identify the negative impact of anthropogenic load on the agro–ecosystem.

Agricultural landscapes within watershed basins experience anthropogenic pressure. Considering the complex interaction of factors in modern ecosystems, there is a need to identify environmental issues and determine key indicators for ecologically safe functioning of agricultural landscapes within river basins.

One of the important environmental problems is chemical pollution of water ecosystems in the basin of the small river due to anthropogenic impact. Uncontrolled discharge of wastewater from municipal treatment plants leads to chemical contamination of surface waters within the settlement of Tlumach.

Agroecological monitoring has been conducted to determine the levels of biogenic elements, salt composition, microelements, and heavy metals in surface and groundwater, as well as the physico–chemical and agrochemical composition of soils within the watershed basin of the Tlumachyk River.

For the Ivano–Frankivsk region of Ukraine, significant territorial diversity of soil cover and land resources is characteristic. Almost all agricultural soil groups are found here. In the southeast of the region, there are large areas of chernozems, which are favorable for agriculture. In terms of total surface water resources, Ivano–Frankivsk region ranks third in Ukraine.

Surface waters in the region belong to the Dnister and Prut river basins. The total number of watercourses in the territory of the region exceeds 8,300, with a total length of 15,656 kilometers. Among them, there are 188 rivers longer than 10 kilometers, including 5 rivers that are longer than 100 kilometers – Dnister, Prut, Svicha, Limnytsia та Bystrytsia з Bystrytsia Nadvirnianska (Kravtsiva, 2013). The climate of Ivano–Frankivsk region has a transitional character, ranging from warm and humid Western European to continental Eastern European, with a distinct vertical bioclimatic zoning. The region belongs to the most industrially developed areas of the Western region of the country. The industrial complex of the region includes over 500 large, medium, and small enterprises of various forms of ownership. Main ecological issues related to the development of mineral deposits in the region. In Ivano–Frankivsk region, 94% of the territory is rural. The region has 765 rural settlements, of which 240 or

31% of the total have mountain status. Rural areas are inhabited by 771.3 thousand people (56% of the total population of the region), or 1013 people on average per settlement (compared to 467 people across Ukraine). This indicates that the anthropogenic impact due to agricultural activities on the environment in Ivano–Frankivsk region is also quite significant. The region is located in the zone of the most humid climate in Ukraine (moisture coefficient 1.5–3.0). To increase the efficiency of land use and its conservation, it is necessary to restore the disrupted balance between forests, water bodies, natural fodder lands, and arable land by reducing the latter, that is, by decreasing the amount of land under cultivation. To prevent negative changes in the main components of agroecosystems in Ivano–Frankivsk region, one important direction is conducting agroecological monitoring in the settlement areas within the watershed of small rivers. This helps identify the main factors causing soil contamination, reducing its fertility, and polluting water sources and agricultural produce. It forms the basis for providing recommendations to reduce the negative anthropogenic impact on the ecological condition of rural settlement territories.

MATERIAL AND METHODS

The research was conducted within the agrolandscapes of Ivano–Frankivsk region, taking into account both stabilizing components (water bodies) and destabilizing components of the ecosystem (agrolandscapes, including agricultural lands - fields, backyard plots). By the method of route monitoring, a survey and sampling of soil and water were conducted in populated areas of Ivano-Frankivsk region within Tlumachka consolidated territorial community (CTC) of Ivano-Frankivsk district. The analysis of natural waters included the Dnister River (Nyzhniv village), Tlumachyk River (right tributary of the Dnister, Tlumach town), right tributaries of the Tlumach River – Dustriv River (Tlumach town) and Mlynivka River (Hrushka village), and left tributaries – Khrust River (Nadorozhna village) and Bzhizhyna River (Tlumach town), as well as ponds (Klubivtsi village, Tlumach town) and springs located in Tlumach town, Lokitka village, Hrushka village, Palahychi village, water from the water intake station (Popeliv village), and soil analysis in Tlumach town, Lokitka village, Klubivtsi village, Melnyky village, and Hrushka village, aimed at determining the direction of migration of biogenic elements and pollutants in the components of the agroecosystem of Tlumachka CTC. Samples of groundwater and soil in the basin of the Tlumachik River were collected in May (Tlumachik River) and August (tributaries of the Tlumachik River) 2022: water – by direct sampling into clean containers, soil – using a soil auger with reference to the sampling locations of water samples.

The Tlumachik River is located within the Tlumachka United Territorial Community of Ivano–Frankivsk district, Ivano–Frankivsk region (Dnister River basin). It is a right tributary of the Dnister River (Black Sea basin). The length of the Tlumachik River is 35 km, with a basin area of 254 km^2. The river gradient is 5.7 m·km^{-1}. The river valley floodplain V-shaped, with a floodplain width ranging from 50 to 300 m. The riverbed meanders, with a width of 6–7 m and a depth of 1.2 m near the mouth. The river meanders and in places shows signs of a lost channel. It originates on the southeastern outskirts of Hostiv village. It flows predominantly northeast and joins the Dnister River east of Nyzhniv village. The river has right tributaries (Dustriv River, Mlynivka River) and left tributaries (Khrust River, Bzhizhyna River). From its source, the main populated places along its course are Tlumach, Honcharivka, Lokitka, Palahychi, Ostrynia, Oleshiv, Antonivka, and Nyzhniv (Figure 1).

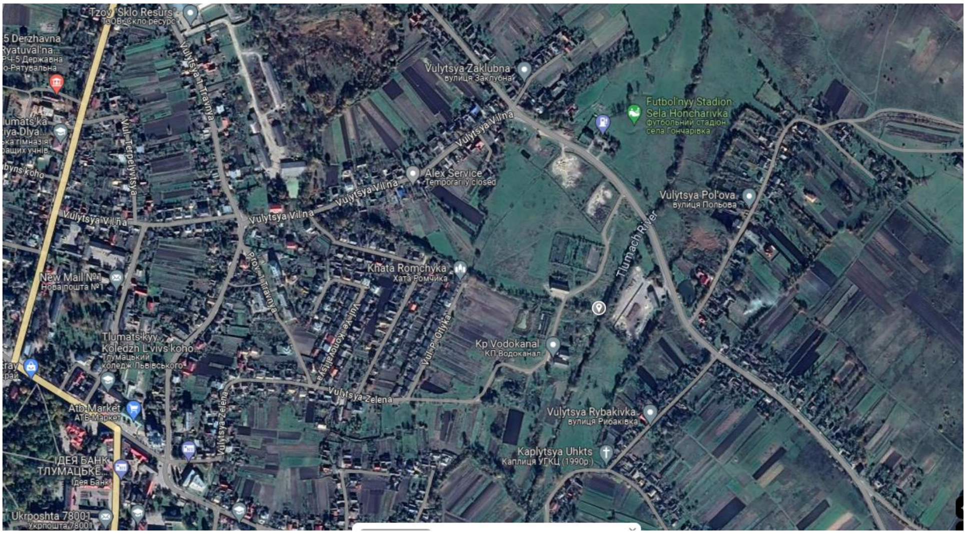

Figure 1. Tlumachik River, Riverbed. Sewage treatment plant (outlet pipe) 48.867655, 25.017406. https://maps.app.goo.gl/iNXf85mSD557HZtn7

In addition to such water quality indicators as acidity according to DSTU 4077-2001, dry residue according to GOST 18164-72, total hardness according to DSTU ISO 6059:2003, the content of various chemical compounds and elements was determined, namely: sulfates according to GOST 4389-72, carbonates and bicarbonates in water extract according to DSTU 7943:2015, nitrates according to GOST 18826-73, phosphorus according to DSTU ISO 6878:2008, chlorides according to DSTU 9297:2007, ammonium according to DSTU ISO 7150-1:2003, potassium according to DSTU ISO 9964-3:2015, as well as copper, manganese, lead, cadmium, zinc, iron, nickel, calcium, magnesium according to GOST 30178-96. In the soil, the following parameters were determined: soil pH (DSTU ISO 10390:2007), hydrolytic acidity (DSTU 7537:2014), organic matter content (humus) (DSTU 4289:2004); light hydrolyzable nitrogen (DSTU 7863:2015); exchangeable potassium and available phosphorus by Kirsanov's method (DSTU 4405:2005), Chirikov's method (DSTU 4115-2002); available compounds of manganese (DSTU 4770.1:2007), available compounds of zinc (DSTU 4770.2:2007), available compounds of cadmium (DSTU 4770.3:2007), available compounds of iron (DSTU 4770.4:2007), available compounds of copper (DSTU 4770.6:2007), available compounds of nickel (DSTU 4770.7:2007), available compounds of lead (DSTU 4770.9:2007); exchangeable calcium and magnesium (DSTU 7861:2015). Chemical-analytical studies of the quality of natural waters and agrochemical studies soil were conducted in the laboratory of the Department of Agroecology and Analytical Research at the Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences of Ukraine, using methods compliant with Ukrainian regulatory standards.

Statistical analysis

The least significant difference at $P<0.05$. Statistical processing was performed by Microsoft Excel in combination with XLSTAT.

RESULTS AND DISCUSSION

The quality of surface water bodies plays an important role in ensuring the social, ecological, and economic well-being of the population living in residential areas. This is why monitoring the condition of surface water bodies is of such great importance. According to Directive 2000/60/EC of the European Parliament and Council of 23 October 2000 establishing a framework for Community action in the field of water policy, Member States must ensure the establishment of water monitoring programs to implement a coherent and comprehensive review of the status of water within each river basin district (Directive of the European Parliament and Council-Document 994_962, 2000). State environmental monitoring of water bodies in Ukraine has a comprehensive approach, but not all water bodies are covered (Shumygai *et al.*, 2021). Climate change, intensive human activity on land, and high plowing of agricultural land are the reasons for the catastrophic destruction of the channels of small rivers, which are becoming shallow, silted, and losing their water flows. There are about 63,000 small rivers in Ukraine, 94% of which have a channel length of up to 10 km. Small rivers are the most vulnerable part of their basins. Their degradation is so evident, but the economic interest of society is the ecological importance of saving small rivers.

Human anthropogenic activity significantly deteriorates the condition of aquatic ecosystems, leading to water quality degradation and threats to human health (Wang and Yang, 2016; Liu *et al*., 2019; Zhao *et al*., 2020; Skyba *et al.*, 2021). Due to low water flow and high connectivity with the surrounding land, small rivers are highly vulnerable to changes caused by natural and anthropogenic factors (Ikauniece and Lagzdiņš, 2020).

The issue of the impact of anthropogenic load on the ecological state of natural waters and soil in river basins is studied by many scientists from different countries. According to Loboda and Katynska (2020), the highest values of anthropogenic impact for the Kryvyi Torets River basin (Druzhkivka) correspond to wastewater discharge (point source pollution) and livestock farming (diffuse pollution). Česonienė *et al.* (2021b) note that the largest volumes of pollution in the river basins of Lithuania are caused by the following sources: transboundary pollution, which contributes 87,599 t ha^{-1} $year^{-1}$ of total nitrogen and 5,020 t ha^{-1} $year^{-1}$ of phosphorus; agricultural pollution, which amounts to 56,031 t ha^{-1} $year^{-1}$ of total nitrogen and 2,474 t ha^{-1} $year^{-1}$ of total phosphorus. Zhao *et al.* (2018) indicate that human activities affect nutrient levels in the soil, potentially acting as non-point sources of pollution in the Mun River basin, which is the largest river in northeastern Thailand. Overall, according to researchers, the main sources of pollution within the river basin are wastewater and agricultural activities.

We conducted agroecological monitoring of surface and groundwater, as well as soils of residential areas within the watershed basin of the Tlumachyk River. The small Tlumachyk River, with a watercourse length of up to 30 km, is characteristic of the right-bank tributaries of the Dnister. A comprehensive ecological survey of the Tlumachyk River channel and its four tributaries was carried out, including the determination of chemical indicators of surface and groundwater, and the agrochemical properties of the soils in the Tlumachka territorial community.

The analysis of the water in the Tlumachyk River in the town of Tlumach (sample 2) showed significant pollution near the treatment facilities (pipe outlet) with ammonium nitrogen compounds (7.2 mg·L^{-1}), phosphorus (1.4 mg·L^{-1}), sulfates (1080 mg·L^{-1}), as well as exceeding the indicators for dry residue content (2152 mg·L^{-1}), hardness (22 mEq·L^{-1}), and calcium (410.5 mg·L^{-1}) (Table 1, Figure 2).

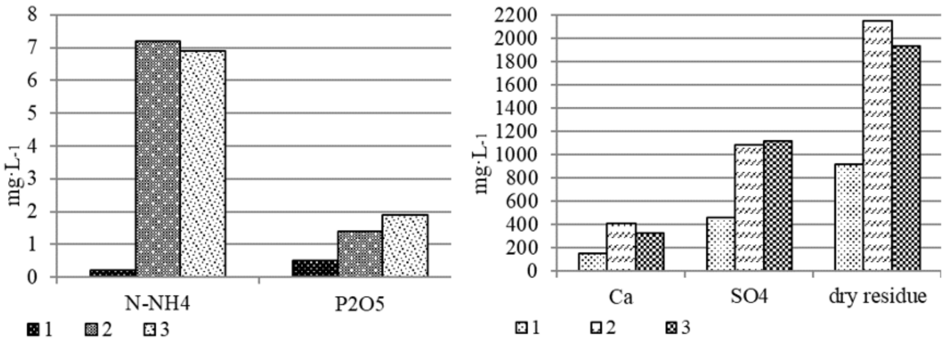

Figure 2. Changes in the content of biogenic elements in river water depending on the distance to the treatment facilities.

Note: 1–Dustryv River, channel 150 m from the treatment facilities, Tlumach; 2–Tlumachyk River, channel, treatment facilities (pipe outlet), Tlumach; 3–Tlumachyk River, 700 m from the treatment facilities, Lokitka village (Ivano-Frankivsk region).

The analysis of the water sampled 700 meters from the treatment facilities in the Tlumachyk River in the village of Lokitka (sample 3) showed a slight decrease in pollution by ammonium nitrogen compounds (6.9 mg·L^{-1}), dry residue content (1936 mg·L^{-1}), hardness (17 mEq·L^{-1}), and calcium (322.7 mg·L^{-1}), and even some increase in pollution by phosphorus compounds (1.9 mg·L^{-1}) and sulfates (1120 mg·L^{-1}).

Table 1. Main indicators of the quality of studied natural waters (rivers) in the territory of Ivano–Frankivsk region (Ivano–Frankivsk district, Tlumachka Unified Territorial Community), 2022

Place of Sampling	pH (environ-mental reaction)	dry resi-due, mg·L⁻¹	Total Hard-ness, mEq·L⁻¹	Ca	Mg	N-NO$_3$	N-NH$_4$	P$_2$O$_5$	K$_2$O	Na$_2$O	HCO$_3$	Cl	SO$_4$
				mg L^{-1}									
1. Dustryv River, 150 meters before the treatment facilities, Tlumach town	7.2	920	9	146.7	21.7	Traces	0.2	0.5	22.4	88.4	434.3	59.6	455.0
2. Tlumachyk River, riverbed, treatment facilities (outlet pipe), Tlumach town	7.4	2152	22	410.5	19.1	Traces	7.2	1.4	9.2	28.7	346.5	45.4	1080.0
3. Tlumachyk River, 700 meters from the treatment facilities, Lokitka village	7.4	1936	17	322.7	17.5	Traces	6.9	1.9	11.2	31.2	302.5	42.6	1120.0
4. Khrust River, 3 km from the source, riverbed, Nadorozhna village	7.9	376	4	62.5	17.5	Traces	0.06	0.2	5.5	35.2	395.3	14.2	9.3
5. Bzhezyna River, estuary, confluence with Tlumachyk River, Tlumach town	7.4	620	6	103.4	14.4	Traces	0.04	0.6	7.3	25.5	302.6	34.1	202.0
6. Mlynivka River, midpoint, 3 km from the source, Hrushka village	7.6	2392	22	426.9	17.4	Traces	0.04	0.2	5.1	14.3	336.7	31.2	1560.0
7. Dniester River, riverbed, Nyzhniv village	8.0	424	5	84.8	12.3	Traces	Traces	0.2	8.5	Traces	253.8	48.3	196.8
$\overline{X} \pm S\overline{x}$	*7.5±0.1*	*1260±329*	*12±3*	*222.5±60.1*	*17.1±1.1*	–	*2.06±1.29*	*0.7±0.2*	*9.9±2.2*	*31.9±10.4*	*338.8±23.0*	*39.3±5.5*	*660.4±222.9*
V, %	*3.9*	*69*	*66*	*71.4*	*17.8*	–	*165.0*	*94.4*	*59.8*	*86.6*	*17.9*	*36.9*	*89.3*
Least Significant Difference (LSD) $_{05}$	*0.4*	*1139*	*10*	*208.2*	*4.0*	–	*4.46*	*0.9*	*7.7*	*27.6*	*79.7*	*19.0*	*772.5*
Quality standards for fisheries water	6.5–8.5	1000	7	180	50	9.1 (40 mg NO$_3$ L^{-1})	0.39 (0.5 mg NH$_4$ L^{-1})	0.46 (0.2 mg PL^{-1})	60 (50 mg K L^{-1})	162 (120 mg Na L^{-1})	Not regulated	300	100

Exceedances in manganese and iron levels in the water of the Tlumachyk River were noted, which may be due to natural factors (high background content in the underlying rocks of the Pre-Carpathian region) (Table 2). In the water of the Dustryv River, a tributary of the Tlumachyk River, flowing 150 meters from the treatment facilities in the town of Tlumach (sample 1), the phosphorus content was 0.5 mg·L^{-1}, sulfates – 455 mg·L^{-1}, and total hardness – 9 mg·L^{-1}, exceeding the quality standards for water intended for fisheries but were significantly lower than the water quality indicators in the Tlumachyk River near the treatment facilities. Therefore, the uncontrolled discharge of wastewater from municipal treatment facilities leads to chemical pollution of surface waters within the Tlumach settlement.

Table 2. Main indicators of the quality of studied natural waters (ponds) in the territory of Ivano–Frankivsk region (Ivano–Frankivsk district, Tlumachka Unified Territorial Community), 2022

Place of Sampling	pH (environ men-tal reac-tion)	dry residue mg·L^{-1}	Total Hardness, mEq·L^{-1}	Ca	Mg	N-NO_3	N-NH_4	P_2O_5	K_2O	Na_2O	HCO_3	Cl	SO_4
				mg·L^{-1}									
1. Pond, 800 meters from the Tlumachyk River, Popeliv village	7.3	2120	4	60.4	8.7	1.1	0.1	0.2	2.5	12.6	200.1	36.9	40.3
2. Tlumachka city lake, midpoint of the Bzhezyna River, Tlumach town	7.6	1228	3	39.8	8.8	Traces	0.1	0.1	2.5	15.5	190.3	36.9	17.8
3. Pond (forest), beginning of the Bzhezyna River, Klyubivtsi village	7.0	292	3	38.4	8.5	Traces	23.5	0.8	4.2	25.5	317.2	31.2	31.7
$\bar{X} \pm S\bar{x}$	*7.3±0.2*	*1213±528*	*3.3±0.3*	*46.2±7.1*	*8.7±0.1*	*0.4±0.3*	*7.9±7.8*	*0.4±0.2*	*3.1±0.6*	*17.9±3.9*	*235.9±40.8*	*35.0±1.9*	*29.9±6.5*
V, %	*4.1*	*75*	*17.3*	*26.7*	*1.8*	*166.3*	*171.0*	*103.2*	*32.0*	*37.9*	*29.9*	*9.4*	*37.9*
LSD_{05}	*1.0*	*914*	*2.0*	*43.2*	*0.5*	*2.2*	*47.4*	*1.3*	*3.4*	*23.8*	*247.9*	*11.5*	*39.9*
Quality standards for fisheries water	6.5–8.5	1000	7	180	50	9.1 (40 mg NO_3 L^{-1})	0.39 (0.5 mg NH_4 L^{-1})	0.46 (0.2 mg P L^{-1})	60 (50 mg K L^{-1})	162 (120 mg Na L^{-1})	Not regulated	300	100

The water in the Mlynivka River, a tributary of the Tlumachyk River in the village of Hrushka (sample 6), also had significant exceedances in quality indicators such as calcium content (426.90 mg·L^{-1}), sulfates (1560 mg·L^{-1}), dry residue (2392 mg·L^{-1}), and hardness (22 mEq·L^{-1}). In the water of this river, an exceedance in copper content (0.01 mg·L^{-1}) was also found, indicating the impact of anthropogenic factors. In the water of the Brzezina River, a tributary of the Tlumachyk River in the town of Tlumach (sample 5), exceedances in sulfate content (202.0 mg·L^{-1}) and manganese content (0.03 mg·L^{-1}) were detected. In the water of the Khrust River tributary in the village of Nadorozhna (sample 4), no exceedance of quality standards was detected, except for manganese content (0.03 mg·L^{-1}). In the water of the Dnister River, flowing near the village of

Nyzhniv (sample 7), to which the Tlumachyk River is a tributary, exceedances in sulfate content (156.8 mg·L^{-1}) and manganese content (0.03 mg·L^{-1}) were also detected. This indicates that pollution by sulfates in the Mlynivka and Brzezina River tributaries, which flow into the Tlumachyk River, as well as in the Tlumachyk River itself, causes these contaminants to enter the Dnister River. Sulfates can be found in detergents, animal waste, fertilizers, pesticides, and naturally occurring minerals in soils, entering groundwater and natural water bodies through natural processes. People who consume water with elevated sulfate levels may experience symptoms such as diarrhea and dehydration. Infants are more sensitive to sulfates than adults. Water containing sulfate levels exceeding 400 mg·L^{-1} should not be used for preparing infant food. Generally, the content of biogenic elements in the tributaries of the Tlumachyk River was found to be lower compared to the quality of surface waters in the Tlumachyk River itself.

The water environment's reaction is an indicator of both natural and anthropogenic origins and varies in river water from nearly neutral to moderately alkaline (pH 7.2–7.9). It is characteristic that increased alkalinity of water is primarily observed in densely populated areas of the Tlumachka community: Khrust River in Nadorozhna village with pH of 7.9, Mlynivka River in Hrushka village with pH of 7.6. Thus, a pattern is identified: the more densely populated the river basin, the higher the alkalinity of the water environment. The study Wang *et al.* (2019) found that changes in pH can significantly impact the productivity of aquatic ecosystems, with acidic water leading to a reduction in productivity and alkaline water leading to an increase in productivity.

Compared to the water of the Dniester River, surface waters of the Tlumachyk River have a less alkaline reaction (pH Dniester River – 8.0, Tlumachyk River – 7.4), significantly higher concentrations of dry residue and sulfates. This indicates that the watershed of the small Tlumachyk River is more vulnerable to intensive pollution by biogenic elements compared to the larger Dniester River. Kim *et al.* (2017) indicate that found that pH plays a critical role in the removal of contaminants, with optimal removal occurring at a pH of 6-8. The study concluded that controlling pH levels is essential for effective contaminant removal from water.

At the time of water sampling, nitrate nitrogen was not detected, while ammonium cation was present in all collected samples ranging from 0.04 to 7.2 mg·L^{-1}. As the samples approached agricultural areas, the $N\text{-}NH_4$ content increased. The highest levels of ammonium nitrogen, 7.2 mg·L^{-1} and 6.9 mg·L^{-1} respectively, were found in the Tlumachyk River (Tlumach town) near the treatment facilities and 700 meters away in Lokitka village. This indicates direct impact of ammonium pollution in surface waters near densely populated residential areas. In the Dniester River, ammonium nitrogen was only present in trace amounts.

In the Tlumachyk River, 700 meters from the treatment facilities (Lokitka village), excess of the quality standard for fisheries due to nickel content was detected (0.04 mg·L^{-1}). In the Dustryv River, 150 meters before the treatment facilities (Tlumach town), zinc content exceeded standards at 0.02 mg·L^{-1}, and in the Mlynivka River, at the midpoint 3 km from its source (Hrushka village), copper content exceeded standards at 0.01 mg·L^{-1}. This can be attributed to the intensive influence of domestic waste on the presence of these elements in surface waters (Table 3). Heavy metals such as lead and cadmium were not detected in any water sample.

Table 3. Main indicators of quality of investigated natural waters (springs) in Ivano–Frankivsk region (Ivano–Frankivsk district, Tlumachka CTC), 2022

Place of Sampling	pH (environmental reaction)	dry residue, mg·L^{-1}	Total Hardness, mEq·L^{-1}	Ca	Mg	N-NO_3	N-NH_4	P_2O_5	K_2O	Na_2O	HCO_3	Cl	SO_4
				mg·L^{-1}									
1. Spring 3 meters deep, 10 meters from the Tlumachyk River channel to the treatment facilities, Lokitka village	7.3	936	9	140.4	28.5	6.9	0.06	0.2	3.2	35.7	356.2	62.5	202.0
2. Spring 11 meters deep, 400 meters from the Tlumachyk River channel, Lokitka village	6.9	2428	27	502.4	19.2	6.8	0.1	0.2	17.2	21.0	405.0	45.4	1772.0
3. Spring 10 meters deep, 1000 meters from the Tlumachyk River channel, Tlumach city	6.9	1412	9	142.4	27.5	12.6	Traces	0.1	1.0	29.8	341.6	82.4	75.6
4. Spring 5 meters deep, 1500 meters from the Tlumachyk River channel, Tlumach city	7.0	860	9	136.7	26.7	10.2	Traces	0.1	0.6	39.4	351.4	59.6	276.5
5. Spring 10 meters deep, 2500 meters from the Tlumachyk River channel, Tlumach city	7.1	360	5	84.1	7.5	4.5	0.06	0.2	0.6	9.5	312.3	34.1	32.5
6. Spring 10 meters deep, 80 meters from the Mlynivka River channel, Hrushka village	6.7	104	2	39.4	3.7	Traces	Traces	0.1	0.6	7.6	92.7	19.9	44.5
7. Spring (active since 1938), 800 meters from the Tlumachyk River channel, Palahychi village	7.1	388	5	78.4	10.8	Traces	Traces	1.4	19.1	40.0	375.8	45.4	45.5
8. Water intake station, Popeliv village	7.3	1040	11	195.4	15.3	Traces	Traces	0.1	6.6	18.4	307.4	34.1	725.0
$\overline{X} \pm S\overline{x}$	7.0±0.1	941±260	10±3	164.9±51.1	17.4±3.4	5.1±1.7	0.04±0.01	0.3±0.2	6.1±2.7	25.2±4.6	317.8±34.1	47.9±7.0	396.7±212.7
V, %	2.9	78	79	87.7	55.3	94.9	92.0	149.1	126.4	51.4	30.3	41.1	151.7
LSD_{05}	0.2	872	9	171.4	11.4	5.8	0.04	0.5	9.1	15.3	114.1	23.3	713.1
Quality standard for drinking and domestic use	6.5–8.5	1500	10	130	80	11.3 (50 mg NO_3 L^{-1})	2.02 (2.6 mg NH_4 L^{-1})	Not regulated	24.1 (2[illegible] mg K L^{-1})*	270 (200 mg Na L^{-1})*	Not regulated	350	500

The monitoring conducted on the model of the Tlumachyk River's surface waters showed that its aquatic ecosystem is vulnerable to environmental disturbances caused by human activities. The river has suffered ecological impact due to the discharge of poorly treated urban wastewater from municipal treatment plants and the influx of biogenic elements from settlements along the river. This scenario sets a precedent for the ecosystem's inability to self-cleanse from excessive harmful substances. The river waters are oversaturated with phosphorus compounds from areas adjacent to the river with treatment facilities and from settlements without proper sewage systems. Phosphorus is considered one of the main elements creating conditions for eutrophication of surface waters. These problems can potentially be addressed through the implementation of a comprehensive ecological program.

In the model of the Tlumachyk River, it is clearly determined that wastewater from treatment plants and settlements near the river's banks, due to the action of organic acids and surfactants contained within them, enhance the influx of predominantly divalent cations such as calcium and magnesium compounds into surface waters. The presence of these compounds determines the concentration of indicators of deterioration that affect water quality. Specifically, there is a direct proportional relationship between the content of dissolved calcium and magnesium ions in water and the content of dry residue, which defines water hardness.

In ecological terms, dry residue serves as a concentrated indicator of water quality, determining the total amount of dissolved mineral inorganic salts including calcium, magnesium, potassium, sodium, heavy metals, and organic substances in the water. Water hardness refers to the saturation of its cations primarily calcium and magnesium–higher concentrations indicate poorer water management properties.

The analysis of water samples collected from a pond located 800 meters away from the Tlumachyk River in Popeliv village (sample 1) and from the Tlumach City Lake (sample 2) showed an excess of dry residue, respectively 2120 and 1228 $mg \cdot L^{-1}$ (Table 2). In the forest pond in Klubivtsi village (sample 3), no excess of dry residue content was noted, but the content of ammonium nitrogen (23.5 $mg \cdot L^{-1}$) and phosphorus (0.8 $mg \cdot L^{-1}$) did not meet the standards, indicating the spread of negative anthropogenic impact not only on ponds located in populated areas but also in natural forest ecosystems. In all ponds, an excess of manganese and iron levels was noted, which may be due to natural factors. Given the natural content of manganese and iron cations in the water bodies of the Tlumachyk River basin, their concentrations reached high levels: 2.8 and 1.67 $mg \cdot L^{-1}$ in the waters of the pond in Popeliv village and 1.27 and 10.1 $mg \cdot L^{-1}$ in the pond in Klubivtsi village, respectively. This is related to the humic nature of the parent rock in these areas and the peat extraction (Table 4). The chemical composition of pond waters, in terms of calcium and magnesium content, shows a tendency for reduced concentrations of biogenic elements compared to the flowing waters of small rivers.

Table 4. Content of trace elements and heavy metals in natural waters (rivers) in the territories of Ivano–Frankivsk region (Ivano–Frankivsk district, Tlumachka CTC), 2022, mg·L^{-1}

Place of Sampling	Cu	Zn	Mn	Fe	Pb	Ni	Cd
	mg·L^{-1}						
1.River Dustriv, riverbed 150 m to the wastewater treatment plants, Tlumach city	Not detected	0.02	0.22	0.25	Not detected	Not detected	Not detected
2.River Tlumachyk, riverbed, wastewater treatment plants (pipe outlet), Tlumach city	Not detected	Not detected	0.04	0.13	Not detected	Not detected	Not detected
3.River Tlumachyk, 700 m from the wastewater treatment plants, Lokitka village	Not detected	Not detected	0.07	0.25	Not detected	0.04	Not detected
4.River Khrust, 3 km from the source, riverbed, Nadorozhna village	Not detected	Not detected	0.03	0.06	Not detected	Not detected	Not detected
5.River Bzhezyna, mouth, confluence with River Tlumachyk, Tlumach city	Not detected	0.01	0.03	0.06	Not detected	Not detected	Not detected
6.River Mlynivka, middle of the river, 3 km from the source, Hrushka village	0.01	Not detected	0.02	Not detected	Not detected	Not detected	Not detected
7.River Dnister, riverbed, Nyzhniv village	Not detected	Not detected	0.03	0.05	Not detected	Not detected	Not detected
$\overline{X} \pm S\bar{x}$	–	–	0.06±0.03	0.11±0.04	–	0.01±0.01	–
V, %	264.6	183.6	113.1	87.6	–	264.6	–
LSD_{05}	–	0.01	0.09	0.13	–	0.02	–
Norms for the quality of water intended for fisheries	0.001	0.01	0.01	0.1	0.1	0.01	0.005

In water bodies with low flow rates, the lowest water hardness was determined, approaching soft values of 3–4 mg-eq·L^{-1}. With a maximum allowable concentration (MAC) of 0.01 mg·L^{-1} for zinc, its content exceeded critical values in the forest pond in Klubivtsi village, reaching 0.03 mg·L^{-1}, which is likely related to natural and anthropogenic factors. The content of heavy metals such as copper, lead, and cadmium in the ponds was not detected.

In the water taken from the water supply station (sample 8), there was also an exceedance of the indicators for calcium content (195.4 mg·L^{-1}), sulfates (725.4 mg·L^{-1}), and hardness (11 mg-eq·L^{-1}) (Table 5).

Table 5. Content of Microelements and Heavy Metals in Natural Waters (Ponds) in the Territory of Ivano–Frankivsk Oblast (Ivano–Frankivsk District, Tlumachka CTC), 2022, mg·L^{-1}

Place of Sampling	Cu	Zn	Mn	Fe	Pb	Ni	Cd
	mg·L^{-1}						
1. Pond, 800 m from the riverbed of the Tlumachyk River, village Popeliv	Not detected	0.01	2.80	1.67	Not detected	0.01	Not detected
2. Tlumach City Lake, middle of the Bzhezina River, city Tlumach	Not detected	Not detected	0.09	0.30	Not detected	Not detected	Not detected
3. Pond (forest), beginning of the Bzhezina River, village Klubivtsi	Not detected	0.03	1.27	10.1	Not detected	Not detected	Not detected
$\overline{X} \pm S\bar{x}$	–	0.01±0.01	1.39±0.78	4.02±3.06	–	–	–
V, %	–	114.6	97.9	131.9	–	173.2	–
LSD_{05}	–	0.05	4.77	18.6	–	0.02	–
Water Quality Standard for Fisheries	0.001	0.01	0.01	0.1	0.1	0.01	0.005

During the expedition, drinking water samples were collected from wells in the Tlumach community. The predominant depth of groundwater is 10 meters, and the distance of the wells from riverbeds ranges from 10–100 meters to 1.0–1.5 kilometers. Groundwater within the Tlumach belongs to non–pressure underground waters, formed as a result of atmospheric precipitation infiltration and water vapor condensation. These waters are generally characterized by a neutral reaction of the water environment but are subject to local contamination depending on the intensity of household activities in the homeowner's yard.

The analysis of water from the well in Lokitka village, located 400 meters from the Tlumachyk River and the sewage treatment facilities, also showed significant exceedances in dry residue content (2428 mg·L^{-1}), hardness (27 mg-eq·L^{-1}), calcium (502.4 mg·L^{-1}), and sulfates (1772 mg·L^{-1}) (sample 2) (Figure 3).

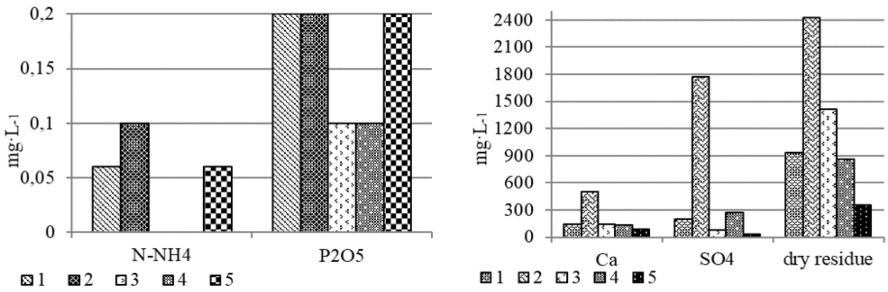

Figure 3. Changes in the content of biogenic elements in well water depending on the distance to the sewage treatment facilities: 1 – 10 meters from the Tlumachyk River to the sewage treatment facilities, Lokitka village; 2 – 400 meters from the Tlumachyk River, Lokitka village; 3 – 1000 meters from the Tlumachyk River, Tlumach town; 4 – 1500 meters from the Tlumachyk River, Tlumach town; 5 – 2500 meters from the Tlumachyk River, Tlumach town (Ivano-Frankivsk region)

In the well (sample 1) located 10 meters from the Tlumachyk River to the sewage treatment facilities, water quality indicators met the standards except for calcium content (140.4 mg·L^{-1}). In the well located 1000 meters from the Tlumachyk River in Tlumach (sample 3), water quality indicators showed exceedances in calcium content (142.4 mg·L^{-1}), nitrate nitrogen (12.6 mg·L^{-1}), and zinc (1.04 mg·L^{-1}). In the well located 1500 meters from the Tlumachyk River (sample 4), only the calcium content exceeded the standard (136.7 mg·L^{-1}), while in the well located 2500 meters away (sample 5), all indicators met the standards.

Groundwater from wells in the Tlumachyk River basin generally has a neutral reaction of the aqueous solution. Nitrate contamination of drinking water is one of the most significant issues for many regions of Ukraine. Within the Tlumach community, nitrate contamination in well water was practically absent during the summer. The content of ammonium nitrogen was mostly detected in trace amounts. The content of phosphorus, potassium, sodium, and chlorides in the well waters was below the established regulatory values. No exceedances were found for magnesium content in the wells of the Tlumachyk River basin. The presence of lead, cadmium, nickel, copper, manganese, and iron was not detected in the groundwater (Table 6). In one of the wells studied, a slight exceedance of zinc content was found.

Table 6. Content of Microelements and Heavy Metals in Natural Waters (Wells) in the Territory of Ivano–Frankivsk Oblast (Ivano–Frankivsk District, Tlumachka CTC), 2022, mg·L^{-1}

Sampling location	Cu	Zn	Mn	Fe	Pb	Ni	Cd
	mg·L^{-1}						
1. Well, 3 m deep, 10 m from the riverbed of the Tlumachyk River to the treatment facilities, village Lokitka	Not detected	0.08	0.02	0.07	Not detected	Not detected	Not detected
2. Well, 11 m deep, 400 m from the riverbed of the Tlumachyk River, village Lokitka	0.01	0.31	Not detected	0.01	Not detected	0.01	Not detected
3. Well, 10 m deep, 1000 m from the riverbed of the Tlumachyk River, city Tlumach	Not detected	1.04	0.01	0.01	Not detected	0.01	Not detected
4. Well, 5 m deep, 1500 m from the riverbed of the Tlumachyk River, city Tlumach	0.03	0.10	0.02	0.02	Not detected	Not detected	Not detected
5. Well, 10 m deep, 2500 m from the riverbed of the Tlumachyk River, city Tlumach	Not detected	Not detecte d	0.02	0.04	Not detected	Not detected	Not detected
6. Well, 10.0 m deep, 80 m from the riverbed of the Mlynivka River, village Hrushka	Not detected	Not detected	0.03	0.13	Not detected	Not detected	Not detected
7. Well (operating since 1938), 800 m from the riverbed of the Tlumachyk River, village Palagychi	Not detected	0.01	0.04	0.01	Not detected	Not detected	Not detected
8. Water intake station, village Popeliv	Not detected	0.01	0.04	0.01	Not detected	Not detected	Not detected
$\overline{X} \pm S\overline{x}$	0.01± 0.0	0.19± 0.13	0.02± 0.0	0.04± 0.02	–	–	–
V, %	213.8	184.4	61.7	114.7	–	185.2	–
LSD_{05}	0.01	0.42	0.02	0.05	–	0.01	–
Standard for drinking and domestic purposes	1.0'	1.0'	0.5	1.0	0.01'	0.02'	0.001'

Note.'– tandards for water supply systems according to State Sanitary Norms and Rules "Hygienic Requirements for Drinking Water Intended for Human Consumption" – 2.2.4-171-10

Thus, due to anthropogenic impact, pollution of natural waters occurs, which negatively affects the redistribution of elements and substances in the biosphere, leading to the accumulation of harmful compounds in well water at a distance of up to 1000 meters from the pollution source. The water in the well located 80 meters from the Mlynivka River in the village of Hrushka (sample 6) and in the well in operation since 1938 (sample 7) located 800 meters from the Tlumachyk River in the village of Palahychi was within regulatory standards.

Wells in the households of settlements serve as the closest indicators of point-source pollution in the surrounding natural environment, as the intensive use of one's own and neighboring properties directly affects the quality of drinking water through gravitational waters. Household factors include septic tanks, outdoor toilets, animal manure, garbage, and others. In addition, the level of carbonate pollution and water hardness is also determined by the properties of the aquifers.

Considering the results of the obtained studies, it is important to provide recommendations to reduce the negative anthropogenic impact on the ecological state of rural residential areas located within river basins. These recommendations include reducing the doses of manure application, minimizing the use of plant protection products (and if used, being sure to know what and in what quantities), keeping livestock and poultry in special enclosures, and adhering to minimum sanitary protection distances for farm buildings. All of this is possible through agroecological monitoring of rural residential areas, which allows identifying the main factors causing soil pollution.

During the water sampling process, soil samples were also collected for agrochemical evaluation. The soil cover of the Tlumachyk River basin is mainly represented by the following types: dark gray podzolic medium loam soils in the upper reaches of the river, and gray and light gray soils in the middle and lower reaches of the river. As one approaches the Dniester River in the northern part of the region, these soils transition into chernozems, and near the Dniester in the northeast, they transition into meadow chernozem soils. All soil types are highly fertile but have their own characteristics due to genetic traits. The soil cover of the Tlumachyk River basin falls into the category of medium and high fertility based on humus content and nutrient regime, which is associated with the high agronomic quality of the parent rocks, enriched with divalent calcium and magnesium cations.

The analysis of soil taken from a household garden in the village of Lokitka, where the owner applies a lot of organic fertilizers from livestock, showed very high levels of mobile phosphorus and potassium, at 410 and 247.5 $mg \cdot kg^{-1}$, respectively, high calcium content at 19.8 meq/100 g, and elevated magnesium at 2.4 meq/100 g (sample 2) (Tables 7, 8). The water analysis from the well of this household, located 400 meters from the Tlumachyk River and treatment facilities, also showed significant exceedances in indicators of dry residue content (2428 $mg \cdot L^{-1}$), hardness (27 $meq \cdot L^{-1}$), calcium (502.4 $mg \cdot L^{-1}$), and sulfates (1772 $mg \cdot L^{-1}$) (sample 4). In the garden located on the property in the city of Tlumach, very high levels of mobile phosphorus (462.5 $mg \cdot kg^{-1}$) and high levels of potassium (132.5 $mg \cdot kg^{-1}$) were also noted. However, the water analysis from the well located 2500 meters from the Tlumachyk River treatment facilities showed that all indicators met the standards. Therefore, keeping a significant number of livestock on the property, uncontrolled application of organic fertilizers to the household plot, and the short distance to the treatment facilities could have caused excessive amounts of phosphorus and potassium in the soil and contamination of the well water of the household owner who keeps a significant number of livestock.

In the village of Hrushka, 15 meters from the left bank of the Mlynivka River on a field for grazing poultry (sample 5), the analyzed soil samples showed elevated levels of easily hydrolyzable nitrogen (231.1 mg·kg^{-1}), very high levels of mobile phosphorus (288.5 mg·kg^{-1}), elevated potassium (117.5 mg·kg^{-1}), and very high levels of calcium (51.8 meq/100 g), which may be due to the large amount of bird droppings.

Table 7. The physical–chemical and agrochemical condition of soils in the territory of Ivano–Frankivsk region (Ivano–Frankivsk district, Tlumachka united territorial community), layer 0–20 cm, 2022

№	Place of Sampling	Exchangeable Acidity, pHsol.	Hydrolytic Acidity, meq/100 g	Organic Matter Content Recalculated to Humus, %	Easily Hydrolyzed Nitrogen, N	Available Phosphorus, P_2O_5	Available Potassium, K_2O
					meq/100 g		
1	Tlumach city, 20 meters from the right bank (treatment facilities), Tlumachyk River.	6.6	0.87	5.03	196.0	80.0	270.0
2	Lokitka village, private property, garden (where a lot of organic fertilizers from livestock are applied).	6.5	0.64	3.62	117.6	410.0	247.5
3	Klubivtsi village, 20 meters from the lake, field (winter rapeseed).	4.6	4.52	3.58	140.0	53.0*	109.5*
4	Melnyky village, 100 meters from the lake, on the left side of the dam, field (winter wheat).	5.4	2.02	4.15	140.0	142.5	247.5
5	Hrushka village, 15 meters from the left bank of the Mlynivka River, field (for grazing poultry), 3 kilometers from the source.	7.1	0.93	5.78	231.1	288.5	117.5
6	Tlumach city, Vavilova Street 9, garden, private property.	7.0	0.49	2.45	81.2	462.5	132.5
	$\bar{X} \pm S\bar{x}$	*6.2±0.4*	6.2±0.4	1.58±0.63	4.10±0.48	150.9±22.1	276.7±67.4
	V, %	15.9	29.4				
	LSD_{05}	1.5	15.9	97.5	28.7	35.9	59.7

The analysis of soil samples taken from fields in Klubivtsi village (winter rapeseed) and Melnyky village (winter wheat) indicated increased soil acidity and decreased fertility compared to soil samples taken from household gardens. In the soil sampled in Tlumach city, located 20 meters from the Tlumachyk River treatment facilities, moderate levels of easily hydrolyzable nitrogen (196 mg·kg^{-1}) and very high levels of mobile potassium (270 mg·kg^{-1}) were observed.

Table 8. The content of microelements, heavy metals, calcium, and magnesium in soils in the territory of Ivano–Frankivsk region (Ivano–Frankivsk district, Tlumachka united territorial community), layer 0–20 cm, 2022

Sample	Place of Sampling	Cu	Zn	Pb	Ni	Cd	Mn	Fe	Ca	Mg
		Mobile forms (extracted with acetate-ammonium buffer solution pH 4.8), $mg \cdot kg^{-1}$							meq/100 g	
1	Tlumach city, 20 meters from the right bank (treatment facilities), Tlumachyk River	0.42	1.6	1.7	1.1	0.15	16.8	6.2	21.6	2.1
2	Lokitka village, private property, garden (where a lot of organic fertilizers from livestock are applied)	0.12	1.3	1.0	0.8	0.15	17.8	0.8	19.8	2.4
3	Klubivtsi village, 20 meters from the lake, field (winter rapeseed).	0.21	1.0	1.4	2.2	0.16	40.1	40.2	12.7	2.2
4	Melnyky village, 100 meters from the lake, on the left side of the dam, field (winter wheat)	0.18	0.8	1.2	0.9	0.12	15.7	3.7	57.9	2.1
5	Hrushka village, 15 meters from the left bank of the Mlynivka River, field (for grazing poultry), 3 kilometers from the source	0.54	2.3	3.1	1.2	0.22	20.1	15.9	51.8	2.0
6	Tlumach city, Vavilova Street 9, garden, private property.	0.22	2.0	1.8	0.7	0.15	13.0	1.4	24.3	2.3
	$\overline{X} \pm S\overline{x}$	*0.28± 0.07*	*1.5± 0.2*	*1.7± 0.3*	*1.1± 0.2*	*0.16± 0.01*	*20.6± 4.02*	*20.6± 4.0*	*11.4± 6.2*	*2.2± 0.1*
	V, %	*57.5*	*38.6*	*44.0*	*47.5*	*20.9*	*47.8*	*47.8*	*133.3*	*6.7*
	LSD_{05}	*0.24*	*0.9*	*1.1*	*0.8*	*0.05*	*14.6*	*14.6*	*22.5*	*0.2*
	Maximum permissible concentration (MPC)									
		3	23	6	4	0.7	–	–	–	–

Overall, soils sampled in the Tlumachyk River basin had a neutral reaction, with an average humus content of 4.6%. In specific locations, particularly in Hrushka village (Mlynivka River), Tlumach city (mouth of the Solonyk River), Melnyky village (mouth of the Solonyk and Mlynivka rivers), the humus content was high, ranging from 5.8% to 8.5%. The average content of easily hydrolyzable nitrogen was 161 $mg \cdot kg^{-1}$, indicating an elevated supply level. The mobile phosphorus content was 210 $mg \cdot kg^{-1}$, and potassium was 229 $mg \cdot kg^{-1}$, both indicating high to very high supply levels with significant variability. The content of microelements and heavy metals did not exceed the maximum permissible concentration (MPC) values.

Thus, the analysis of soil samples in the Tlumachyk, Mlynivka, and Bzhizhyna River basins indicates a sanitary-safe level of heavy metal contamination in the arable layer, except for isolated cases in areas with high anthropogenic loads. This will enable the designation of areas for organic farming and livestock as profitable sectors of agricultural production in the future. However, about 30% of the soil cover is eroded, significant areas are unproductive with shrub overgrowth, and grasslands are low-yielding, requiring a systemic approach to the restoration of the Tlumachyk River basin.

Due to the fact that the ecological condition of suburban areas often does not meet sanitary and hygienic standards and rules, which is associated with small areas of backyard plots that are often not maintained due to lack of knowledge and awareness among rural populations, it is necessary to implement education on ecological issues in rural communities. This education should cover potential problems arising from uncontrolled use of organic and mineral fertilizers, pesticides and plant disease control agents, livestock and poultry management, storage of manure, and failure to maintain adequate distances from water supply sources to outbuildings, privies, compost pits, and garbage bins on backyard plots.

As a result of anthropogenic influence, pollution of natural waters and soil occurs in suburban areas, negatively affecting the redistribution of elements and substances in the biosphere, leading to accumulation of compounds such as calcium, sulfates, significant exceedance of dry residue and hardness indicators in well water within 400 meters from the pollution source, and excessive accumulation of available phosphorus and potassium in the soil. To improve the quality of surface and groundwater and prevent their chemical pollution, it is necessary to construct modern standardized treatment facilities within the settlements of the small river basin and establish centralized sanitary–hygienic purification systems.

CONCLUSIONS

1. Agroecological survey of the Tlumachyk River basin in the Tlumachska amalgamated territorial community (CTC) of Ivano-Frankivsk district, Ivano-Frankivsk region, was conducted. The basin stretches for 35 km with an area of 254 km², including 4 tributaries: the right ones are Dustriv and Mlynivka, and the left ones are Khrust and Bzhezyna. Tlumachska OTG comprises 18,099 residents across 34 villages, focusing on agricultural activities.

2. Two field expeditions were conducted for reconnaissance and sampling of surface and subsurface water, ponds, and soil in the floodplain of the Tlumachyk River to determine agrochemical characteristics, cation composition of macro– and microelements, and heavy metals for the agroecological assessment of the river basin.

3. The chemical composition determination of surface waters collected from the Tlumachyk River revealed a direct correlation between the increase in concentration of dry residue, ammonium nitrogen, total phosphorus and potassium forms, sodium, bicarbonates, chlorides, and sulfates with the intensity of anthropogenic influence on water quality. These elements serve as indicators of chemical pollution by biogenic elements due to their high concentrations. The highest degree of surface water pollution was identified near the urban sewage treatment plants of Tlumachyk and settlements located in protective zones along the river banks. Nearly 70% of water samples showed elevated concentrations of phosphorus compounds, increased water hardness, carbonate content, and levels of iron, manganese, and nickel, which increase with increasing anthropogenic load. Copper, zinc, lead, and cadmium content in Tlumachyk River waters are almost absent. Generally, the content of biogenic elements in the Tlumachyk River tributaries was lower compared to the quality of surface waters in the Tlumachyk River itself.

3.1. Monitoring conducted on a model of the Tlumachyk River's surface waters showed that its aquatic ecosystem is vulnerable to environmental disturbances caused by human activities. The river has suffered an ecological impact due to the discharge of poorly treated sewage from urban sewage treatment plants and the influx of biogenic elements from settlements along the river. This creates a precedent of the ecosystem's inability to self-cleanse from an excess of harmful substances. The river waters are oversaturated with phosphorus compounds in areas adjacent to sewage treatment facilities and settlements without proper sewage systems.

3.2. In the forest pond in the village of Klubivtsi, excess levels of ammonium nitrogen (23.5 $mg \cdot L^{-1}$) and phosphorus (0.8 $mg \cdot L^{-1}$) indicate the spread of negative anthropogenic influence not only on ponds located in areas directly inhabited by the population but also in natural forest ecosystems.

3.3. All investigated ponds show excess levels of manganese and iron, which may be due to natural factors. The chemical composition of pond waters in terms of calcium and magnesium tends to lower the concentration of biogenic elements compared to the flow waters of small rivers.

3.4. Due to the low flow rate of water in the ponds, they have the lowest water hardness, approaching soft values of 3–4 $mg\text{-}eq \cdot L^{-1}$. Zinc content exceeded critical levels in the forest pond in the village of Klubivtsi, reaching 0.03 $mg \cdot L^{-1}$, which is evidently linked to natural and anthropogenic factors. The presence of heavy metals such as copper, lead, and cadmium in the ponds was not detected.

4. Groundwater from springs in the basin of the Tlumachyk River mostly has a neutral pH. Within the Tlumachka region, nitrate pollution in spring waters during summer was practically absent. Ammonium nitrogen content was mostly trace amounts. Phosphorus, potassium, sodium, and chloride levels in spring waters were below regulatory limits. Magnesium content in the springs of the Tlumachyk basin did not exceed permissible levels. Lead, cadmium, nickel, copper, manganese, and iron were not detected in groundwater.

4.1. A spring located 400 m from the Tlumachyk River and sewage treatment facilities (village of Lokitka) showed significant exceedances in dry residue content (2428 $mg \cdot L^{-1}$), hardness (27 $mg\text{-}eq \cdot L^{-1}$), calcium (502.4 $mg \cdot L^{-1}$), and sulfates (1772 $mg \cdot L^{-1}$). At a distance of 1000 m from the Tlumachyk River in Tlumach town, water quality indicators in the spring exceeded limits for calcium (142.4 $mg \cdot L^{-1}$), nitrate nitrogen (12.6 $mg \cdot L^{-1}$), and zinc (1.04 $mg \cdot L^{-1}$). At 1500 m from the river, only calcium content exceeded the standard (136.7 $mg \cdot L^{-1}$), while at 2500 m, all indicators met regulatory norms. This indicates that anthropogenic influence leads to pollution of natural waters, adversely affecting the distribution of elements and substances in the biosphere, resulting in the accumulation of harmful substances in well water within 1000 m of the pollution source.

5. Agronomic monitoring of rural settlement areas reveals the main factors contributing to soil contamination. Based on the research results, reducing the application rates of manure, minimizing the use of plant protection products, and maintaining agricultural grasslands and poultry in designated areas will contribute to improving the ecological situation of rural settlement areas.

5.1. The soil cover of the Tlumachyk River basin, as determined from collected samples, exhibits a neutral reaction, with an average humus content of 4.6%. In specific locations, humus content is high, ranging from 5.8% to 8.5% (in villages such as Hrushka, along the Solonyk River mouth in Tlumach, and in Melnyky near the Solonyk and Mlynivka rivers). The average content of hydrolyzable nitrogen is 161 $mg·kg^{-1}$, indicating an elevated level of availability. Available phosphorus levels are 210 $mg·kg^{-1}$, and potassium levels are 229 $mg·kg^{-1}$, indicating high to very high availability. The content of microelements such as copper, zinc, manganese, and nickel in the soil samples collected is below the sanitary and hygienic standards (GDK), as is the content of heavy metals.

5.2. Overall, the soil cover is characterized as potentially highly fertile, with areas that could potentially be suitable for organic farming. However, approximately 30% of the soil cover has been eroded, with significant areas being unproductive, overgrown with shrubs, and low-yielding grasslands, which requires a systematic approach to the basin's restoration issues along the Tlumachyk River.

In general, the basin of the Tlumachyk River can be classified as an ecologically balanced region with local manifestations of environmental stress in areas of high anthropogenic pressure. These areas include the vicinity of wastewater treatment plants at the headwaters of the Tlumachyk River, settlements located directly along the riverbank, tributaries of the Tlumachyk River, and ponds. Restoring the Tlumachyk River basin requires a complex of engineering and cultural-technical measures to restore watercourses and fisheries, as well as to bring the sanitary–hygienic conditions of the community in line with environmental standards.

REFERENCES

Andel, I. V. (2013). Ecological Migration of Population in the Regions of Ukraine. Socio-economic problems of the modern period of Ukraine, 3(101): 451–457. [in Ukraine]

Česonienė, L., Šileikienė, D. & Dapkienė, M. (2021b). Influence of Anthropogenic Load in River Basins on River Water Status: A Case Study in Lithuania. Land, 10(12): 1312. https://doi.org/10.3390/land10121312

Česonienė, L., Šileikienė, D., Marozas, V. & Čiteikė, L. (2021a). Influence of Anthropogenic Loads on Surface Water Status: A Case Study in Lithuania. Sustainability, 13(8): 4341. https://doi.org/10.3390/su13084341

Davydiuk, H. V., Shkarivska, L. I., Klymenko, I. I., Dovbash, N. I. & Demianiuk, O. S. (2020). Quality of natural waters in agrolandscapes of the Forest-Steppe zone depending on anthropogenic load. Balanced nsture management, 3: 115–120. https://doi.org/10.33730/2310-4678.3.2020.212612 [in Ukraine]

Directive of the European Parliament and Council 2000/60/ЄC of 23 October 2000 establishing a framework for Community action in the field of water policy. (2000). Document 994_962, current, latest version – Version from 20.11.2014. https://zakon.rada.gov.ua/laws/show/994_962#Text

Doroshenko, A. V. (2017). Anthropogenic impact on the river basins of the Forest-Steppe Zone of Ukraine: theoretical and methodological aspects. Taurida Scientific Herald. Series: Rural Sciences, (97): 217–228. https://www.tnv-agro.ksauniv.ks.ua/archives/97_2017/37.pdf [in Ukraine]

DSTU 4077-2001. (2002). Water quality. Water quality – Determination of pH (ISO 10523:1994, MOD). [Effective from 2002.03.12]. Kiev. State Consumer Standard of Ukraine. [in Ukraine]

DSTU 4115-2002. (2003). Soils. Determination of mobile compounds of phosphorus and potassium by the modified Chirikov method. [Effective from 2003-01-01]. Kyiv, State Committee of Ukraine for Technological Regulation and Consumer Policy. [in Ukraine]

DSTU 4289:2004. (2005). Soil quality. Methods for determining organic matter. [Effective from 2005-07-01]. Kiev. State Consumer Standard of Ukraine. [in Ukraine]

DSTU 4405:2005. (2006). Soil quality. Determination of mobile compounds of phosphorus and potassium by Kirsanov method modified by NSC ISSAR. [Effective from 2006-07-01]. Kiev. State Consumer Standard of Ukraine. [in Ukraine]

DSTU 4770.1:2007. (2009). Soil quality. Determination of manganese mobile compounds content in soil in bufferd ammonium-acetate extract with pH 4.8 by atomic-absorption spectrophotometry. [Effective from 2009-01-01]. Kiev. State Consumer Standard of Ukraine. [in Ukraine]

DSTU 4770.2:2007. (2009). Soil quality. Determination of zinc mobile compounds content in soil in bufferd ammoniumacetate extract with pH 4.8 by atomic-absorption spectrophotometry". [Effective from 2009-01-01]. Kiev. State Consumer Standard of Ukraine. [in Ukraine]

DSTU 4770.3:2007. (2009). Soil quality. Determination of cadmium mobile compounds content in soil in bufferd ammoniumacetate extract with pH 4.8 by atomic-absorption spectrophotometry. [Effective from 2009-01-01]. Kiev. State Consumer Standard of Ukraine. [in Ukraine]

DSTU 4770.4:2007. (2009). Soil quality. Determination of iron mobile compounds content in soil in bufferd ammoniumacetate extract with pH 4.8 by atomic-absorption spectrophotometry. [Effective from 2009-01-01]. Kiev. State Consumer Standard of Ukraine. [in Ukraine]

DSTU 4770.6:2007. (2009). Soil quality. Determination of copper mobile compounds content in soil in bufferd ammoniumacetate extract with pH 4.8 by atomic-absorption spectrophotometry. [Effective from 2009-01-01]. Kiev. State Consumer Standard of Ukraine. [in Ukraine]

DSTU 4770.7:2007. (2009). Soil quality. Determination of nickel mobile compounds content in soil in bufferd ammoniumacetate extract with pH 4.8 by atomic-absorption spectrophotometry. [Effective from 2009-01-01]. Kiev. State Consumer Standard of Ukraine. [in Ukraine]

DSTU 4770.9:2007. (2009). Soil quality. Determination of lead mobile compounds content in soil in bufferd ammoniumacetate extract with pH 4.8 by atomic-absorption spectrophotometry. [Effective from 2009-01-01]. Kiev. State Consumer Standard of Ukraine. [in Ukraine]

DSTU 7537:2014. (2015). Soil quality. Soil quality hydrolytic acidity determination. [Effective from 2015-04-01]. Kiev. State Consumer Standard of Ukraine. [in Ukraine]

DSTU 7861:2015. (2020). Soil quality. Determination of exchanges calcium, magnesium, sodium and potassium in soil according to Shollenberger in nsc issar named afte O. N. Sokolovsky modification. [in Ukraine]
DSTU 7863:2015. (2015). Soil quality. Determination of easily hydrolyzable nitrogen by the Kornfield. [in Ukraine]
DSTU 7943:2015. (2015). Soil quality. Carbonates and bicarbonates ions definition in water extract. [Effective from 2016-09-01]. Kiev. State Consumer Standard of Ukraine. [in Ukraine]
DSTU 9297:2007. (2007). Water quality – Determination of chloride –- Silver nitrate titration with chromate indicator (Mohr's method) (ISO 9297:1989, IDT). Kiev. State Consumer Standard of Ukraine. [in Ukraine]
DSTU ISO 10390:2007. (2012). Soil quality. Soil quality – Determination of pH (ISO 10390:2005, IDT). [Effective from 2009-10-01]. Kiev. State Consumer Standard of Ukraine. [in Ukraine]
DSTU ISO 6059:2003. (2004). Water quality – Determination of the sum of calcium and magnesium. EDTA titrimetric method. [in Ukraine]
DSTU ISO 6878:2008. (2018). Water quality – Determination of phosphorus – Ammonium molybdate spectrometric method (ISO 6878:2004, IDT). Kiev. State Consumer Standard of Ukraine. [in Ukraine]
DSTU ISO 7150-1:2003. (2004). Water quality – Determination of ammonium – Part 1. Manual spectrometric method (ISO 7150/1:1984, IDT). Kiev. State Consumer Standard of Ukraine. [in Ukraine]
DSTU ISO 9964-3:2015. (2015). Water quality - Determination of sodium and potassium – Part 3: Determination of sodium and potassium by flame emission spectrometry (ISO 9964-3:1993, IDT). Kiev. State Consumer Standard of Ukraine. [in Ukraine]
GOST 18164-72. (1972). Drinking water. Method for determination of total solids content. [in Russian]
GOST 18826-73. (1973). Drinking Water. Methods for determination of Nitrates Content. [in Russian]
GOST 30178-96. (2001). Raw material and food-stuffs. Atomic absorption method for determination of toxic elements. [in Russian]
GOST 4389-72. (1974). Drinking water. Method for determination of sulphate content. [in Russian]
Havryliuk, O. S., Kondratenko, T. Y., Mezhenskyj, V. M., Shevchuk, L. M., Baranovska, O. D., Tonkha, O. L., Litvinov, D. V. & Mazur, B. M. (2024). Photosynthetic potential of Malus domestica columnar group. Regulatory Mechanisms in Biosystems, 15(1): 3–9. https://doi.org/10.15421/022401
Ikauniece, K. & Lagzdiņš, A. (2020). The assessment of chemical and ecological status in the water bodies of slocene and age. Research for rural development, 35: 241–247. https://doi.org/10.22616/rrd.26.2020.035
Jiang, Y., Chen, S., Hu, B., Zhou, Y., Liang, Z., Jia, X., Huang, M., Wei, J. & Shi, Z. (2020). A comprehensive framework for assessing the impact of potential agricultural pollution on grain security and human health in economically developed areas. Environmental Pollution, 263: 114–653. https://doi.org/10.1016/j.envpol.2020.114653
Kanianska, R. (2016). Agriculture and Its Impact on Land Use, Environment, and Ecosystem Services. Landscape Ecology: 1–25. https://doi.org/10.5772/63719

Kim, S. K., Kim, J. H., & Kim, S. H. (2017). Effects of pH on the removal of nutrients from wastewater. Water Science and Technology, 76(10): 2767–2774. https://doi.org/10.2166/wst.2017.424.

Korsun, S. G. & Palapa N. V. (2014). Social and ecological condition of the territories of rural settlements of Ukraine. Collectionof scientific works of the National Research Center «Institute of Agriculture NAAS», 1–2: 9–16. [in Ukraine]

Kravtsiva, V. S. (2013). The Carpathian region: current problems and development prospects. Environmental safety and natural resource potential, 1: 336. https://www.nas.gov.ua/UA/MultiVolumeBook/Pages/Default.aspx?MVBID=0000222 [in Ukraine]

Litvinova, O., Degodyuk, S., Litvinov, D., Symochko, L., Zhukova, Y. & Kyrylchuk, A. (2021). The impact of agrochemical loading on nutritive regime of grey forest soil during field crop rotation. International Journal of Ecosystems and Ecology Science (IJEES), 11(4): 831–836. https://doi.org/10.31407/IJEES11.421

Litvinova, O., Dehodiuk, S., Litvinov, D., Havryliuk, O., Kyrychenko, A., Borys, N. & Dmytrenko, O. (2023a). Efficiency of technology elements for growing winter wheat on typical chernozem. Agronomy research, 21(3): 1199–1212. https://doi.org/10.15159/AR.23.079

Litvinova, O., Litvinov, D., Degodyuk, S., Romanova, S. &Rasevich, V. (2020). Effect of fertilizers systems on accumulation of heavy metals in gray forest soil. International Journal of Ecosystems and Ecology Science (IJEES), 10(4): 603–608. https://doi.org/10.31407/ijees10.404

Litvinova, O., Litvinov, D., Romanova, S. & Kovalyova, S. (2019). Soil biological activity under the human-induced impact in the farmed ecosystem. International Journal of Ecosystems and Ecology Science (IJEES), 9(3): 529–536. https://doi.org/10.31407/ijees9316

Litvinova, O., Tonkha, O., Havryliuk, O., Litvinov, D., Symochko, L., Dehodiuk, S. & Zhyla, R. (2023b). Fertilizers and Pesticides Impact on Surface-Active Substances Accumulation in the Dark Gray Podzolic Soils. Journal of Ecological Engineering, 24(7): 119–127. https://doi.org/10.12911/22998993/163480

Liu, J., Han, G., Liu, X., Liu, M., Song, C., Zhang, Q., Yang, K. & Li, X. (2019). Impacts of Anthropogenic Changes on the Mun River Water: Insight from Spatio-Distributions and Relationship of C and N Species in Northeast Thailand. International Journal of Environmental Research and Public Health, 16(4): 659. https://doi.org/10.3390/ijerph16040659

Loboda, N. S. & Katynska, I. V. (2020). Determination of main anthropogenic impacts and environmental risks for the Kryvyi Torets river basin (based on the EU Support Program for Ukrainian water policy). Ukrainian hydrometeorological journal, (25): 81–92. https://doi.org/10.31481/uhmj.25.2020.08 [in Ukraine]

Lototska, O. V., Kondratiuk, V. A. & Kucher, S. V. (2019). Quality of drinking water as one of the determinants of public health in the Western region of Ukraine. Bulletin of Social Hygiene and Health Protection Organization of Ukraine, 1(79): 12–18. https://doi.org/10.11603/1681-2786.2019.1.10278 [in Ukraine]

Mahananda, M. R., Mohanty, B. P. & Behera, N. R. (2010). Physico-chemical analysis of surface and ground water of bargarh district, Orissa, India. International Journal of Research and Reviews in Applied Sciences, 2(3): 284–295. http://arpapress.com/Volumes/Vol2Issue3/IJRRAS_2_3_10.pdf

Nikolaichuk, V. I., Vakerich, M. M., Shpontak, J. M. & Karpu'k M. K. (2015). The current state of water resources of Transcarpathia. Biosystems Diversity, 23(2): 116–123. doi: https://doi.org/10.15421/011517

Palapa, N. V., Ustymenko, O. V. & Sihalova, I. O. (2017). Ecological assessment of rural settlements. Agroecological journal, 2: 89–95. https://doi.org/10.33730/2077-4893.2.2017.220163.

Pavlichenko, A., Dmytrenko, O., Litvinova, O., Kovalova, S., Litvinov, D. & Havryliuk, O. (2023). Changes in gray forest soil organic matter pools under anthropogenic load in agrocenoses. Agronomy research, 21(3): 1266–1277. https://doi.org/10.15159/AR.23.095

Prykhodko, M. M. (2012). Ecological risks of contamination of geosystems of the Ukrainian Carpathian region and adjacent territories. Scientific Herald of Chernivtsi University: Geography, (614–615): 95–104. [in Ukraine]

Radchenko, M., Kabanets, V., Sobko, M., Murach, O., Butenko, A., Pivtoraiko, V., Burko, L. & Skydan, M. (2024b). Formation of productivity and grain quality of peas depending on plant growth regulator. Agriculture and Forestry, 70(2): 135–148. https://doi.org/10.17707/AgricultForest.70.2.10

Radchenko, M., Trotsenko, V., Butenko, A., Hotvianska A., Gulenko O., Nozdrina N., Karpenko O. & Rozhko, V. (2024a). Influence of seeding rate on the productivity and quality of soft spring wheat grain. Agriculture and Forestry, 70(1): 91–103 https://doi.org/10.17707/AgricultForest. 70.1.06

Sasakova, N., Gregova, G., Takacova, D., Takacova, J., Papajova, J., Venglovsky, J., Szaboova T. & Kovacova S. (2018). Pollution of Surface and Ground Water by Sources Related to Agricultural Activities. Frontiers in Sustainable Food Systems, 2(42). https://doi.org/10.3389/fsufs.2018.00042

Shkarivska, L. I., Davydiuk, H. V., Klymenko, I. I., Dovbash, N. I. & Hirnyk, V. V. (2021). Hirnyk Drinking water quality of decentralized water supply in rural settlements of the Forest-steppe zone. Agriculture and Crop Production: Theory and Practice, 1(1): 48–53. https://zemlerobstvo.com/wp-content/uploads/2021/11/zemlerobstvo-01_2021.pdf [in Ukraine]

Shumygai, I. V., Mudrak, O. V., Konishchuk, V. V., Mudrak H. V. & Khrystetska M. V. (2021). Ecological monitoring of water bodies in Central Polissya (Ukraine). Ukrainian Journal of Ecology, 11(2): 434–440. https://www.ujecology.com/articles/ecological-monitoring-of-water-bodies-in-central-polissya-ukraine.pdf

Skyba, V. P., Kopylova, O. M., Vozniuk, N. M., Likho, O. A., Pryshchepa, A. M, Budnik, Z. M., Gromachenko K. Y. & Turchina, K. P. (2021). Ecological risks in river basins: a comparative analysis of steppe and forest Ukrainian areas. Ukrainian Journal of Ecology, 11(1): 306–314. https://doi.org/10.15421/2021_46

The Law of Ukraine "On the Basic Principles (Strategy) of the State Environmental Policy of Ukraine for the Period Until 2030". Document 2697-VIII, valid, current edition. https://zakon.rada.gov.ua/laws/show/2697-19#Text [in Ukraine]

Valerko, R. A. & Herasymchuk, L. O. (2020). Ecological assessment of the condition of rural settlements of Zhytomyr region. Ecological Sciences, 6(33): 96–102. https://doi.org/10.32846/2306-9716/2020.eco.6-33.14 [in Ukraine]

Voitovyk, M., Butenko, A., Prymak, I., Mishchenko, Yu., Tkachenko, M., Tsiuk, O., Panchenko, O., Slieptsov, Yu., Kopylova, T. & Havryliuk, O. (2023). Influence of fertilizing and tillage systems on humus content of typical chernozem. Agraarteadus, 34(1): 44–50. https://dx.doi.org/10.15159/jas.23.03

Wang, Q. & Yang, Z. (2016). Industrial water pollution, water environment treatment, and health risks in China. Environmental Pollution, 218: 358–365. https://doi.org/10.1016/j.envpol.2016.07.011

Wang, Y., Zhang, Y., Wang, L., Wang, W., & Zhang, Q. (2019). Effects of pH on the productivity of aquatic ecosystems. Journal of Environmental Management, 248: 109320. https://doi.org/10.1016/j.jenvman.2019.109320.

Wilson, G. (2010). Multifunctional 'quality' and rural community resilience. Transactions of the Institute of British Geographers New Series, 35(3): 364–381. https://doi.org/10.1111/j.1475-5661.2010.00391.x

Zhao, K., Wu, H., Chen, W., Sun, W., Zhang, H., Duan, W., Chen, W. & He, B. (2020). Impacts of Landscapes on Water Quality in A Typical Headwater Catchment, Southeastern China. Sustainability, 12(2): 721. doi.org/10.3390/su12020721

Zhao, Z., Liu, G., Liu, Q., Huang, C. & Li, H. (2018). Studies on the Spatiotemporal Variability of River Water Quality and Its Relationships with Soil and Precipitation: A Case Study of the Mun River Basin in Thailand. International Journal of Environmental Research and Public Health, 15(11): 2466. https://doi.org/10.3390/ijerph15112466