PROTECTION OF WATER AND BIODIVERSITY

ANALYSIS AND RECOMMENDATIONS FOR SUSTAINABLE DEVELOPMENT OF THE TRESKA RIVER

This study is produced as part of the project „Youth Activism for a Sustainable River: Protection and Promotion of Biodiversity in the Treska River“ supported by the Embassy of Canada through the Canada Fund for Local Initiatives. The content of the study is the responsibility of the Association for Policy Research ANALYTICA think tank and does not necessarily reflect the views of the funding partner.

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Content

1. Introduction

Rivers represent one of the most valuable natural resources, playing a key role in maintaining ecosystems and providing water for drinking, agriculture and industrial activities. Their importance is not only ecological, but also economic and cultural, as they are the backbone of the communities that live next to them and are also home to numerous rare and endemic species. But, in recent decades, rivers have come under increasing pressure from pollution, destruction of natural habitats and the consequences of unsustainable infrastructure projects.

The Treska River is one of the most important water resources of the Republic of North Macedonia, which faces serious challenges. Despite the fact that according to the physical-chemical parameters the water has good quality, the wastewater from the surrounding villages and inadequate waste management lead to its bacteriological pollution, classifying it in the fourth class according to bacteriological quality. This condition has serious implications on biodiversity, but also on people who depend on the river for their daily needs.

Field research, documenting the condition of the riverbed and laboratory analyses of the water are key to understanding the extent of pollution and developing efficient protection measures. These analyses not only reveal the presence of pollutants, but also enable the comparison of conditions between different locations and time periods, enabling the detection of potential sources of pollution.

By protecting the Treska River and its habitats, we will not only protect the rare and endemic species that depend on it, but also ensure sustainable development for future generations.

This publication aims to encourage all interested parties to take immediate action to conserve this precious natural resource.

2.Purpose and object of the research

The purpose of this research is to document and identify threats and impacts on the Treska River, which will contribute to monitoring the condition of the river ecosystem and habitats, as well as to the preservation of natural resources that are essential for local communities. Namely, this research will provide key information for local and national authorities, which they will be able to use in developing new effective practices for monitoring the river, as well as in planning new measures for the protection and restoration of river ecosystems. In addition, it will encourage the active participation of the local population by inducing them to the importance of maintaining healthy river habitats.

One of the key aspects of the research is improving the water quality of the Treska River and minimizing the health risks associated with groundwater pollution, which is often used as a source of drinking water through wells, captured springs and public taps. Groundwater pollution not only affects human health, but also seriously affects the entire ecosystem.

As part of this research, the results of laboratory research carried out in the Central Environmental Laboratory, which is part of the Ministry of Environment and Physical Planning, as well as results of analyses of previous measurements carried out by the Institute of Public Health – Skopje, will be presented. Recommendations based on the obtained results will be submitted to local and national authorities in order to initiate new policies and practices for the restoration of rivers and river habitats, which will contribute to the long-term protection of water resources.

Panoramic picture of the confluence of the Treska River with the Vardar River

3. About the Project

This publication was prepared within the framework of the project „Youth Activism for a Sustainable River: Protection and Promotion of Biodiversity in the Treska River", which is financially supported by the Embassy of Canada for Serbia, Montenegro and North Macedonia. The main goal of this project is the protection of water and biodiversity in the Treska River, as well as strengthening of youth and citizen participation through the application of citizen science. Young activists and representatives from local civil society organizations actively participate in the project in order to raise awareness of environmental problems and encourage community engagement.

The initiative for this project stems from the current environmental crisis in the Republic of North Macedonia, where air pollution is at the top of the lists in Europe, waste is almost never recycled, and the level and quality of water in rivers and lakes are in constant decline. Illegal logging and arson are destroying forests, threatening endemic animal species and biodiversity, which is on the verge of extinction.

Namely, the project „Youth Activism for a Sustainable River: Protection and Promotion of Biodiversity in the Treska River" aims to initiate specific actions to improve the water condition of the Treska River as well as the protection of local flora and fauna, through the establishment of partnerships between youth, civil society organizations and local and national authorities. Through the application of citizen science, participants will be able to contribute to the collection of data, analysis of problems and proposal of solutions, which will create a platform for active engagement of young people in environmental protection. The importance of this project is in the protection of the Treska River, as well as in encouraging community responsibility and building awareness for sustainable management of natural resources.

Confluence of the Treska River with the Vardar River. Location at the end of the recreation center Park Saraj. 2024

4. Hydrographic and climatic characteristics

Length, width and area for all running water

Treska, in the Kichevo Valley known as Golema Reka, is the third longest Vardar tributary. It springs from a karst hot spring that occurs on the southern branch of the mountain Bistra, below the Kiska peak in the village of Izvor in Kopacka at 740 m above sea level, and flows into Vardar in the Skopje Valley near the village Saraj, at an altitude of 260 m. The total length of the river is 138 km, with a drop of 480 meters and a watershed area of 2,068 km2 or 8.04% of the territory of R. North Macedonia.

In its evolutionary development, Treska built Kichevo Gorge (14.0 km), Brod Gorge (17.5 km) and Golema Gorge (66.2 km), and intersects the Kichevo Valley, the Brod alluvial river expansion, Poreche and a small part of the Skopje Valley. Previous research (J. Cviić, P. Jovanović, B. Milojevic) has determined that Treska has a piratical valley, which consists of two rivers: one that flowed into Skopje Lake - Dolna Treska and another that flowed into Poreche Lake - Gorna Treska. The one that flowed into Poreche Lake drained through Barbaras and Ushi in Pelagonija. With the drainage of Skopje Lake, the lower erosive base in Skopje Valley descended, an increase in vertical erosion occurred, which caused a backward movement of the spring of Dolna Treska and its penetration into the Poreche basin. Thus, it drains the water from Poreche Lake and carries out piracy of the upper flow, i.e. Gorna Treska, and creating a unique valley. In this valley, there are currently two accumulation lakes: Matka and Kozjak. The middle flow of the Treska River, around the village of Zdunje, is referred to by the local population as Gorna Treska, while the upper basin around Brod is called Dolna Treska, which does not correspond to reality.

The density of the river network is 209 m/km2, and the Treska River receives 13 larger tributaries, specifically eight from the left side and five from the right side.

The left tributaries of the Treska River are: Studenchica (13.8 km), Zajaska River (27.1 km), Rabetinska River (12.2 km), Devichka River (13.0 km), Slatinska River (16.2 km), Topolnichka River (12.6 km), Mala River or Crneshnica (27 km), and Suva River or Fush (25.6 km). Among them, Studenchica has the greatest slope (52%), while Zajaska River has the largest watershed area of 295 km2. The spring of Studenchica is captated and based on its yield of 800 l/s, a regional water

Geographic map of the watershed area of the Treska River supply system has been built from which Kichevo, M. Brod, Krushevo, and Prilep are supplied with water.

The major right tributaries of the Treska River are: Belichka River (15.7 km), Slaneshnica (12.2 km), Krapska River (4.1 km - a sinkhole), Beleshnica (5.8 km), and the Ocha River (4 km, also a sinkhole).

Depth and area for all still water

Kozjak Lake - It is located on the Treska River in its Golema Gorge, 15 km upstream from the Matka dam. The lake has multiple purposes, such as electricity production, irrigation, water supply for the city of Skopje and other settlements, and flood protection.

Matka Lake - It is located on the Treska River at its exit from the Golema (Shishevo) Gorge. The dam is an arch, reinforced concrete structure, built in 1938. Constructed near Skopje, with a distinctly attractive surrounding, this lake is today one of the most visited excursion spots in the vicinity of Skopje.

Artificial Lake – Accumulation Sveta Petka - It is located between the Kozjak and Matka accumulations.

Recreational Lake Treska – It is located in the municipality of Saraj, in close proximity to the village of Glumovo. It has a kidney shape with a total area of 13 ha and an average depth of 2 meters. The maximum depth is 3 meters. Essentially, it is a flowing lake and is filled through an inlet channel, which is partially closed, from the Treska River. Water from the lake flows through an overflow into a closed channel and re-flows into the Treska River. The primary purpose for which the accumulation was constructed, is recreation and swimming; however, due to the poor quality of the inlet water (the inlet channel is connected to sewage networks from houses in the vacation settlement and villages above the accumulation), swimming has been prohibited for a longer period.

The environmental conditions and the quality of the water allow for significant biological production and intensive fish growth in the accumulation.

* hectare, a unit of area in the metric system equal to 100 ares or 10,000 square meters

Basic climatic characteristics of the geographical area

From a climatic perspective, the watershed of the Treska River falls into several homogeneous temperature regions, namely: Kichevo Valley, Makedonski Brod, Polog Valley, and Skopje Valley. The climatic conditions represent an average of the climatic conditions in the four neighboring regions. The average monthly temperatures in the winter months range from 0.3 to -3.7°C, indicating that snowfall does not persist for long.

The Kichevo Valley is deeply nestled among high, forested mountain massifs. Its altitude ranges from 600 to 700 meters. The average annual temperature is 10.8 °C. The average January temperature is below zero, while the average temperatures for December and February are significantly higher. The extreme minima can reach as low as -25.7°C (Lazarevski, 1993)*.

Precipitation in the Kichevo Valley is unevenly distributed. In the autumn and winter periods, 58.7% of the total annual precipitation, while 25% occurs in the spring. The remaining 16.3% are during the summer months. The high humidity period in the valley occurs during the winter months, and from March, humidity decreases towards the summer months, only to increase again in the autumn.

In tems of thermic characteristics, the climate in the Kichevo Valley is as follows: January is a cold month, February and December are also cold months, March and November are moderately cold, April and October are moderately warm, May, June, and September are warm months, while July and August are hot months. Evapotranspiration increases steadily from spring to summer due to the semi-dry to dry climate that dominates from April to October. This indicates the reasons for the reduction in water yield of river flows and karst springs during the summer and autumn periods, which is confirmed by the dynamics of the hydrological condition of the Treska River throughout the year.

The climate in the Makedonski Brod Valley differs from that in the Kichevo Valley. A key characteristic is that the average monthly temperatures during the winter months are always above zero. The average January temperatures are significantly higher than those in the Kichevo Valley. The forested massifs have an influence here, and their effect on the climate is evident.

The Polog Valley is the northwestern to western neighbor of the Treska Gorge. The climatic characteristics of the Polog Valley are very similar to those of the Kichevo Valley. The average values of the monthly temperatures in the winter period are relatively lower than those in the Kichevo Valley. The average winter temperatures range from 0.7 to 1.8°C, while the climate in the spring is warmer, which is influenced by the width of the valley and the relatively lesser forestation of the mountain massifs. The Suva Gora massif from the Tetovo side is bare.

In spring, the average temperatures range from 6.1 to 15.8°C, and these values are similar to those in autumn, which range from 6.3 to 16.7°C. The summer period is warmer than that in the Kichevo Valley, with average temperatures ranging from 19.4 to 21.4°C. Precipitation in the Polog Valley is approximately identical to that in the Kichevo Valley. The annual average precipitation amounts to 783 mm. The richest months in terms of precipitation are autumn and winter, when 54.7% of the total precipitation falls. In the spring months, 25.4% of the total precipitation occurs, while the remaining approximately 20% falls during the summer period.

* Klimata vo Makedonija, Angel Lazarevski, Kultura

The average monthly temperatures in the Skopje Valley are the highest compared to those in the Kichevo, Brod, and Polog Valleys. The average annual temperature is 12.5°C. Another characteristic is that all average monthly temperatures are above zero. In the winter period, the average temperatures range from 1.6 to 3.9°C, in the spring months from 7.8 to 17.7°C, while in the summer period they range from 20.1 to 23.2 °C. The autumn period is approximately equal to the fluctuations in spring, reaching values from 7.1 to 18.5°C. In the Skopje Valley, the monthly totals of precipitation are significantly lower. In the autumn and winter period, 51.9% of the precipitation falls. In the spring months, it is 27.2%, and in the summer period, it is 20.9%.

5. Basic Biological Characteristics

The basic biological characteristics of Treska River include macrophyte vegetation, phytoplankton and zooplankton, as well as macrozoobenthos. Plant species such as Potamogeton and Muriophilum are present in certain parts of the river, while Treska Lake has a variety of macrophyte vegetation. Plankton organisms are not significant for the ecosystem, due to the lack of conditions for their development.

As for the macrozoobenthos, spring organisms are the most abundant in the spring region of Treska River, which indicates the high quality of the water. The benthic fauna in the estuary area of the river, towards Vardar, is different. Research shows a predominance of chironomids, which are a significant food source for fish.

The presence of oligochaetes and chironomids indicates that the water from the confluence of the Treska River has a **β-mesosaprobic** character, suggesting moderate organic pollution.

Analysis of macroinvertebrates in the upper reaches of Treska River showed that they are present in large quantities, providing abundant food for fish that feed on bottom organisms (bentophagous fish) and fish that feed on a variety of food sources (omnivorous fish). This indicates that the river provides good feeding conditions for these types of fish. In the waters of the Treska River, you can find: the river crayfish - Astacus astacus, the green frog and others.

In the past, the freshwater crayfish was regularly found in the area before the confluence with the Vardar River, but today its population has drastically decreased and is in question. Bearing in mind that it is a part of the river flow, which is not under strong pressure of waste water and heavy pollution, the question arises as to what are the reasons for the reduction of river crayfish populations. The green frog is a common inhabitant of the Treska River waters, especially in the slow, slow-flowing parts of the river.

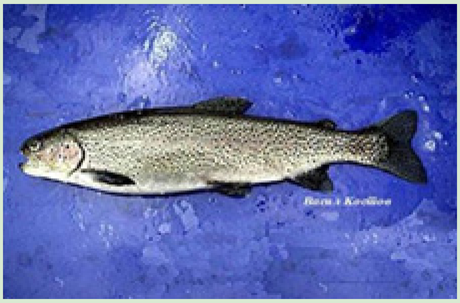
Species and Quantities of Fish - Ichthyomass

Salmo macedonicus (Macedonian trout)

The Macedonian trout is an autochthonous and endemic species of fish, characteristic of the waters of the Republic of North Macedonia. It is found scattered in cold mountain streams and rivers with clean, clear water, rich in oxygen. It inhabits the upper flow of the Vardar River with its tributaries from the upper flow, then the upper flows of the tributaries from the middle flow of Vardar, the rivers: Treska with its tributaries, Lepenec, Kadina Reka, Pcinja with its tributaries, Topolka, Babuna with its tributaries, Bregalnica with its tributaries. Its presence in the Boshava and Doshnica rivers is also certain.

Onchorhynchus mykis - Californian trout, rainbow trout

The center for the cultivation of Californian trout is the watershed of the Sacramento River in the state of California, USA, on the eastern shore of the Pacific Ocean. From there, it has been distributed worldwide and represents a major object of breeding in cold-water fish farms, as well as a popular sport and recreational species in artificial accumulations. In our country, as well as globally, it holds significant economic importance. Through intensive selection, strains have been developed with exceptionally favorable and commercially profitable traits. It is disease-resistant, breeds easily, grows rapidly, and is resilient to temperature changes.



Alburnus sp. – Plashica, belviche, plashka

In the waters of the Republic of North Macedonia, we distinguish several species of plashica. Plashica that lives in the waters of the Vardar basin is defined as S. thessalicus. It lives both in stagnant oligotrophic and eutrophic ecosystems, and in flowing ecosystems, mainly in the middle and lower flows of rivers. It lives in large and small flocks and mainly stays in the upper layers of the water.

Barbus balcanicus - Black barbel (Balkan barbel, flow barbel).

According to the latest taxonomy in the Republic of North Macedonia, we differentiate several species that were once collectively referred to as „black barbel“. Today, the fish that inhabit the waters of the Vardar River, previously designated as „black barbel“ are now identified as „Balkan barbel”, making distinction from the fish that inhabit the waters of the Strumica basin and the Prespa-Ohrid basin, specifically the Crn Drim basin, which were also once labeled as „black barbel“. It is one of the most commonly caught fish in all waterflows of North Macedonia where it resides.

Barbus macedonicus - Macedonian barbel, white barbel, river barbel.

According to the new taxonomy, the subspecies of the white barbel Barbus barbus macedonicus has been elevated to the level of a species, and today we refer to it as a distinct species Barbus macedonicus - Macedonian barbel.

Carassius gibelio - Silver carp, Chinese carp, carp, babushka

The silver carp is an introduced species in the waters of the Republic of Macedonia. It is also in the group of introduced invasive fish species. It is a species that negatively affects the population density of autochthonous (indigenous) fish species. Today it is present in almost all our waters. Its range of distribution is constantly expanding, as well as the abundance in rivers, lakes and accumulations.

Chondrostoma vardarense – Skobust, skobalj, bojnik

According to the new taxonomy, the subspecies C. nasus vardarensis has been elevated to the level of a species C. vardarense, and today we refer to it as the „Vardar skobust.“ It inhabits the Vardar River and its tributaries, from the Polog Basin to the exit of the Republic of North Macedonia, as well as the waters of the Aegean basin located in Turkey, Bulgaria, Greece, and part of the Aoos River basin in Greece and Albania, which is part of the Adriatic basin.

Cyprinius carpio – Carp

The native habitat of the carp encompasses areas that include China, Japan, Central Asia, and the Black Sea basin (Danube basin). In the Balkans, it inhabits the waters of the Black Sea, Adriatic, and Aegean basins. In Macedonia, it populates the three natural lakes and all major accumulations. It is also found in all riverbeds that flow slowly and have deeper sections.

Pachychilon macedonicum – Mergur

It inhabits the middle and lower flow of the Vardar River and its tributaries, and it is also found in several waterflows in Greece. This is an indisputable endemic species for the central part of the Balkan Peninsula. It is absent from neighboring basins with which the Vardar basin shares many similarities.

Scatdinius erytrophthalmus – Plotica, pisa

The pisa is widespread throughout almost all of Europe, except for the Iberian Peninsula. In the Republic of North Macedonia, it is found in the Vardar River, the Katlanovo Marsh, and the Dojran and Ohrid Lakes. It is also a resident of the Crn Drim River. It is absent from the Treska River but was introduced into the „Recreational Lake Treska“ in 2008. It is already well acclimatized and has successfully spawned.

Squalius vardarensis – Klen, utman

The taxonomy and systematic classification of the klen have changed. In the past, it was classified as a representative of the genus Leuciscus, but it has now been transferred to the genus Squalius. According to older literature, there is one species of klen (Leuciscus cephalus) in the Republic of North Macedonia, along with several subspecies' characteristic of different river basins. Thus, we spoke of L. cephalus vardarensis, L. cephalus prespensis, L. cephalus ohridanus, L. cephalus macedonicus, and others. Today, according to the new classification, certain subspecies have been elevated to the status of separate species, and we now distinguish several different species specific to certain waters: Squalius vardarensis – for the Vardar basin; Squalius prespensis – for Lake Prespa; Squalius orpheus – for the Strumica basin

Cobitis vardarensis – Vardar shtipalka

According to data from older literature, there is a species Cobitis taenia in the Republic of North Macedonia, along with specific populations at the subspecies level for different river basins. According to the new taxonomy, we distinguish several separate species of shtipalki, namely: Vardar shtipalka – C. vardarensis, Ohrid shtipalka – C. ohridana, Prespa shtipalka – C. meridionalis, Strumica shtipalka – C. strumicae, and Balkan shtipalka – C. elongata. The morphological differences among them are minor, so we will not specify them here. The separation into distinct species is primarily based on biochemical and genetic research.

Perca fluviatilis – perkija, kostresh

Perkija is one of the species that is very sensitive to pollution. Although it used to have a stable and dense population in the Vardar River, today its population has been significantly reduced and is nearly extinct. If this trend continues, it is only a matter of time before it (conditionally) becomes completely extinct as an autochthonous species in the flowing ecosystem of the Vardar River.

6. Basic physical-chemical characteristics

Temperature

TTemperature affects the rate of chemical reactions, the rate of photosynthesis in algae and aquatic plants, the metabolic rate of other organisms, as well as how pollutants, parasites, and other pathogens interact with aquatic inhabitants. Temperature is important in aquatic systems because it can cause mortality and can influence the solubility of dissolved oxygen (DO) and other materials in the water column (for example, ammonia). Water temperatures naturally vary both daily and seasonally. The maximum daily temperature usually occurs a few hours after noon, while the minimum is around dawn. Water temperature varies seasonally with air temperature.

Temperature gradients are established due to the physical properties of water, where water is densest at 4°C, ensuring that cooler waters are typically found at the bottom of lakes and deep rivers. Exceptions to this pattern can be found in ice-covered systems, where a reverse temperature gradient may occur, with the upper layer of water being cooler than the lower layer.

Aquatic organisms often have narrow temperature tolerances. Thus, although water bodies have the ability to buffer against extreme atmospheric temperatures, even moderate changes in water temperatures can have serious impacts on aquatic life, including bacteria, algae, invertebrates, and fish.

Thermal pollution occurs in the form of direct impacts, such as the discharge of industrial cooling water into aquatic receiving bodies, or indirectly through human activities.

Lush Vegetation of Woody and Shrubby Plants around the Treska River.

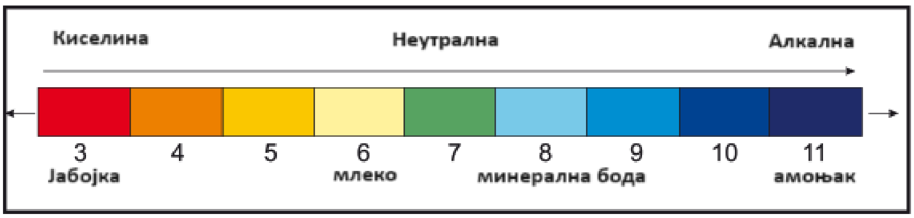
Dissolved oxygen

Dissolved oxygen in the water column is one of the most important components of aquatic systems. Oxygen is essential for the metabolism of aerobic organisms and influences inorganic chemical reactions. Oxygen is often used as an indicator of water quality, with high concentrations typically indicating good water quality. Oxygen enters the water through diffusion across the water surface, through fast movements such as waterfalls or riffles in streams (aeration), or as a product of photosynthesis. The amount of dissolved oxygen largely depends on temperature and to some extent on atmospheric pressure. Salinity also affects dissolved oxygen concentrations, with oxygen levels being low in highly saline waters and vice versa. The amount of any gas, including oxygen, dissolved in water is inversely proportional to the water temperature; as the temperature increases, the amount of dissolved oxygen (gas) decreases.

Many productive lakes experience periods of oxygen depression or depletion in the deep waters during the warm summer months when strong temperature gradients are established between the warm surface and the cold deep water. High algal production in surface waters can lead to reduced oxygen concentrations at depth as the cells die and settle to the bottom of the lake, where they decompose by bacteria. The decomposition process consumes oxygen from the water through bacterial respiration.

pH and Alkalinity

In the water, a small number of water molecules (H_2O) dissociate to form hydrogen (H_2) and hydroxyl (OH_2) ions. If the relative proportion of hydrogen ions is greater than that of hydroxyl ions, then the water is defined as acidic. If hydroxyl ions dominate, then the water is defined as alkaline. The relative proportion of hydrogen and hydroxyl ions is measured on a negative logarithmic scale from 1 (acidic) to 14 (alkaline): 7 is neutral (US EPA , 1997; Friedl et al.).

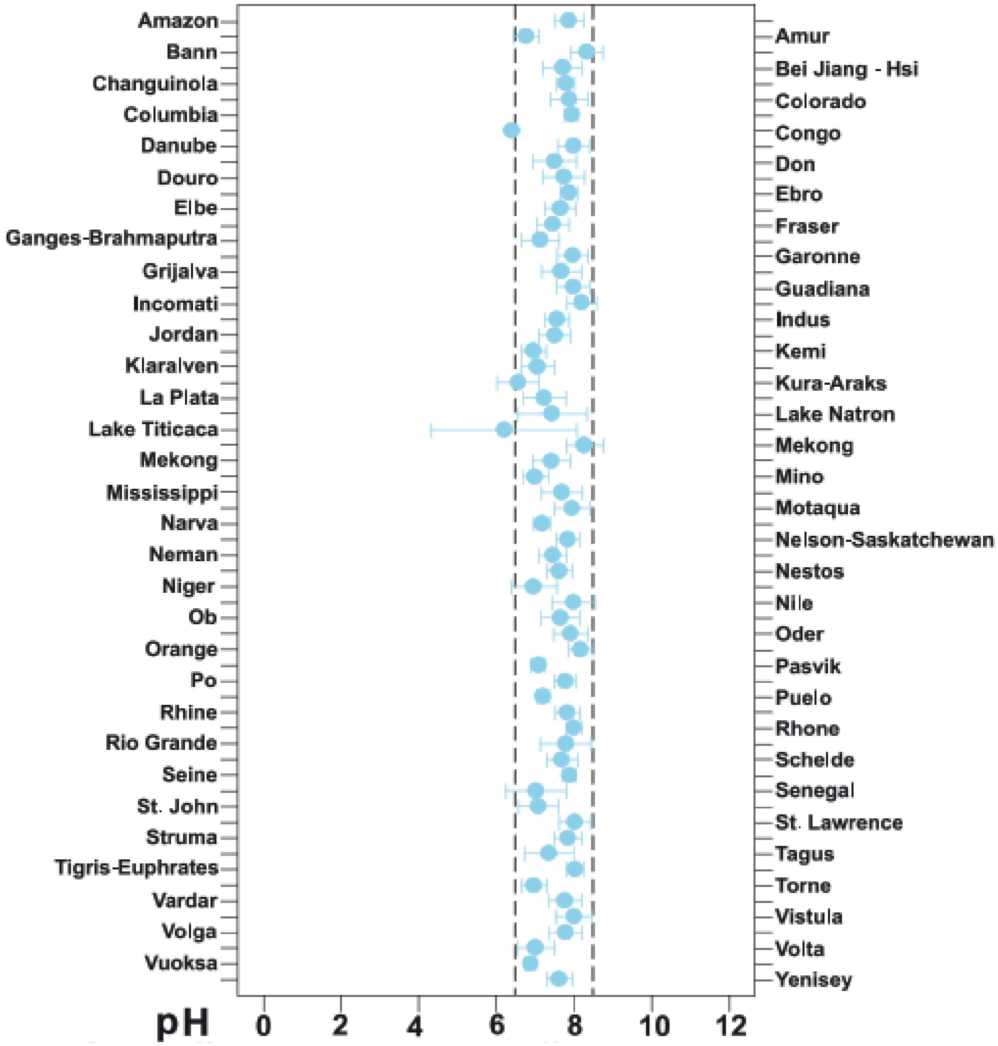


pH - Scale

The pH value of aquatic ecosystems is an important parameter for maintaining biological productivity, as it directly influences the metabolism and growth of organisms. Generally, pH values ranging from 6.5 to 8.5 are considered ideal and indicate a healthy aquatic ecosystem. Within this range, the water supports a greater number of species and provides stable living conditions. The natural acidity of rainwater results from the dissolution of carbon dioxide (CO_2) from the atmosphere, which creates a weak solution of carbonic acid. When rainwater enters aquatic systems, its acidity is neutralized as it passes through

* United States Environmental Protection Agency.

the soil, thanks to the carbonate and silicate minerals present. The degree of this neutralization depends on the retention time of the water in the soil and the amount of minerals such as calcium carbonate and bicarbonates, which regulate the pH value and keep the water within a favorable range for life. (Friedl et al., 2004; Wetzel and Likens, 2000).*



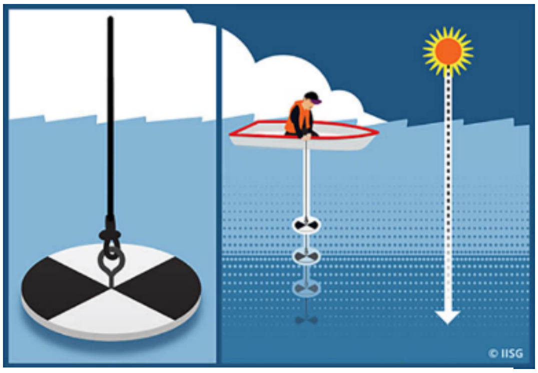
Average pH of major rivers in the world. The dashed lines indicate the approximate pH range suitable for the protection of aquatic life.

Alkalinity is a related concept that is commonly used to indicate the capacity of a system to buffer against the effects of acidity. The buffering capacity is the ability of a water body to resist or mitigate changes in pH value. Alkaline compounds in water, such as bicarbonates, carbonates, and hydroxides, remove H_2 ions and reduce the acidity of the water (i.e., increase the pH value).

* Scientific papers by Friedl et al., 2004; Wetzel and Likens

Turbidity and Suspended Solids

Turbidity refers to the clarity of water. The greater the amount of suspended solids in the water, the cloudier it appears, and the measured turbidity is higher. The main source of turbidity in the open water zone of most lakes is typically phytoplankton, but closer to the shore, the particles may also include clay and silt from shoreline erosion, resuspended sediments from the bottom, and organic waste from streams and/or water discharges. The sources of these sediments include both natural and anthropogenic (human) activities in the watershed, such as natural or excessive soil erosion from agriculture, forestry, or construction, urban runoff, industrial effluents, or excess phytoplankton growth (US EPA, 1997). Turbidity is often expressed as total suspended solids. Water transparency and Secchi disk depth are also commonly used indicators of water quality that quantify the depth of light penetration into the water body. Water bodies with high transparency values typically have good water quality.



Secchi Диск

Salinity and Specific Conductivity

Salinity is an indicator of the concentration of dissolved salts in a water body. The ions responsible for salinity include the main cations (calcium, Ca^{2+}; magnesium, Mg^{2+}; sodium, Na^{+}; and potassium, K^{+}) and the main anions (carbonates, CO_3^{2-} and HCO_3^{-}; sulfate, SO_4^{2-}; and chloride, Cl^{-}). The level of salinity in aquatic systems is important for aquatic plants and animals, as species can only survive within certain salinity ranges (Friedl et al., 2004). Although some species are well adapted to survive in saline environments, the growth and reproduction of many species may be hindered by increasing salinity (Stoddard et al., 1999) *

Nutrients

Nutrients are essential elements for life. The main nutrients, or macronutrients, necessary for the metabolism and growth of organisms include carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, sulfur, magnesium, and calcium. In aquatic systems, nitrogen and phosphorus are the two nutrients that most often limit the maximum biomass of algae and aquatic plants (primary producers), which occurs when the concentrations in the environment fall below the requirements for optimal growth of algae, plants, and bacteria.

There are also many micronutrients needed for the metabolism and growth of organisms, but in most cases, the cellular requirements for these nutrients do not exceed their supply. For example, elements such as iron (Fe) and manganese (Mn) are essential cellular constituents, but they are required in relatively low concentrations compared to their availability in freshwater (US EPA, 1997).

* Scientific papers by Stoddard et al., 1999.

Nitrogen and phosphorus

Compounds of nitrogen (N) and phosphorus (P) are key cellular components of organisms. Since the availability of these elements is often less than the biological demand, environmental sources can regulate or limit the productivity of organisms in aquatic ecosystems. In this way, the productivity of aquatic ecosystems can be managed by regulating the direct or indirect inputs of nitrogen and phosphorus in order to either reduce or increase primary production.

Phosphorus is primarily present in natural waters as phosphates, which can be divided into inorganic and organic phosphates. Phosphates can enter aquatic environments from natural atmospheric influences on the minerals in the watershed, from biological decomposition, and as runoff from human activities in urban and agricultural areas. Inorganic phosphorus, such as orthophosphate (PO_4^{3-}), is biologically available to primary producers that rely on phosphorus for production and has been shown to be an important nutrient that limits the maximum biomass of these organisms in many inland systems. Phosphorus in water is usually measured as total phosphorus, total dissolved phosphorus (i.e., all P that passes through a 0.45 µm pore filter), and soluble reactive or orthophosphorus.

Nitrogen occurs in water in various inorganic and organic forms, and the concentration of each form is primarily mediated by biological activity. Nitrogen fixation, performed by cyanobacteria (blue-green algae) and certain bacteria, converts dissolved molecular N_2 into ammonium (NH_4^+). Aerobic bacteria convert NH_4^+ into nitrate (NO_3^-) and nitrite (NO_2^-) through nitrification, while anaerobic and facultative bacteria convert NO_3^- and NO_2^- into N_2 gas through denitrification. Primary producers assimilate inorganic N as NH_4^+ and NO_3^-, and organic N is returned to the basin of inorganic nutrients through bacterial decomposition and the excretion of NH_4^+ and amino acids by living organisms.

Nitrogen in water is typically measured as total nitrogen, ammonium, nitrate, nitrite, total Kjeldahl nitrogen (= organic nitrogen + NH_4^+), or as a combination of these parameters to assess the concentrations of inorganic or organic nitrogen.

Phosphorus and nitrogen are considered primary drivers of the eutrophication of aquatic ecosystems, where increased nutrient concentrations lead to enhanced primary productivity. Some systems are naturally eutrophic, while others become eutrophic as a result of human activities ("cultural eutrophication") through factors such as runoff from agricultural areas and the discharge of municipal waste into rivers and lakes. Aquatic ecosystems can be classified in trophic condition, which indicates the potential of the system for biomass growth in primary producers. Trophic conditions are typically defined as oligotrophic (low productivity), mesotrophic (moderate productivity), and eutrophic (high productivity).

Ultraoligotrophic and hypereutrophic conditions represent opposite extremes in the classification of trophic status of aquatic environments. Although there are many methods for classifying systems into trophic condition, the common approach examines nutrient concentrations across various systems and categorizes them based on their ranking within the range of nutrient concentration (Dodds et al., 1998). This approach is illustrated in the Figure showing monitoring stations for rivers around the world.

Silicates

Silicates or silicon dioxide (SiO_2) is a key micronutrient in the production of diatoms or silicate algae, which are a very common group of algae and absorb this element during the early stages of their growth. Concentrations of silicon dioxide can limit diatom production if concentrations are depleted in surface waters. The depletion of silicon dioxide tends to occur more frequently in lakes and accumulations than in flowing waters (US EPA, 1997; Cambers and Ghina). During periods of high biological productivity by diatoms, concentrations of silicon dioxide can be depleted from the surface waters of lakes by more than ten times. The reduction of silicon dioxide in surface waters usually leads to a rapid decline in diatom populations.

	Total Phosphorus (mg L^{-1})		
	Station	Oliogotrophic-Mesotrophic boundary	Mesotrophic-Eutrophic boundary
Africa	12	0.21	0.49
Americas	46	0.05	0.10
Asia	144	0.06	0.13
Europe	116	0.10	0.32
Oceania	88	0.10	0.20
Global	406	0.07	0.20

Metals

Metals occur naturally and are integrated into aquatic organisms through food and water. Trace metals such as mercury, copper, selenium, and zinc are essential metabolic components in low concentrations. However, metals tend to bioaccumulate in tissues, meaning prolonged exposure or exposure of organisms to higher concentrations can lead to disease. Increased concentrations of metals required in trace amounts can have negative consequences for both wildlife and humans. Human activities such as mining and heavy industry can result in higher concentrations than would be found naturally.

Metals tend to be strongly associated with sediments in rivers, lakes, and accumulations, and their release into the surrounding water is influenced by pH value, condition of decreasing of oxidation and the organic matter content in the water. Therefore, monitoring water quality for metals should also include sediment concentrations to account for the potential source of metal contamination in surface waters.

Metals in water can pose a serious threat to human health. In particular, arsenic, a metalloid that naturally occurs in some sources of surface and groundwater, can lead to skin lesions and cancer in people exposed to excessive concentrations through drinking water, bathing water, or food. Arsenic can be mobilized from host minerals through anaerobic microbial respiration (i.e., bacteria capable of respiration in the absence of oxygen), as long as there is sufficient organic carbon to sustain metabolism. There are certain well-documented "hot spots" where arsenic in groundwater tends to be high, including Bangladesh and India, and to a lesser extent, Vietnam and Cambodia (Sharle and Polia, 2006). Monitoring metals in the reserves of surface and groundwater, especially those intended for human consumption, provides essential information about the suitability of the resources for use.

* Scientific papers by Dodds et al., 1998.

** Scientific papers by Cambers and Ghina

Mercury

Mercury is a metal that occurs naturally in the environment, but human activities have significantly increased its atmospheric concentration, accounting for approximately 75 percent of emissions worldwide. Anthropogenic sources of mercury in the environment include municipal waste, coal combustion facilities (electricity generation), industrial processes (older methods for producing chlorine and caustic soda), and some consumer products (e.g., batteries, fluorescent lamps, thermometers). The form of mercury that is most concerning from a water quality perspective is Hg^{2+}, as it quickly dissolves in water and, consequently, is the form most commonly encountered in aquatic ecosystems. Mercury in water is usually measured in its total or dissolved form.

When mercury is present in water, some of the microorganisms transform it into methylmercury, which is highly toxic. Methylmercury tends to remain dissolved in water and does not travel far into the atmosphere. However, it can be converted back into elemental mercury and re-emitted into the atmosphere. This "frog-jump" effect can occur multiple times, spreading mercury over large distances. Mercury is concerning because it bioaccumulates in the tissues of animals and humans, sometimes with concentrations tens of thousands of times greater than the source of water, causing reproductive and neurological diseases.

Organic matter

Organic matter plays a key role in the cycles of nutrients, carbon, and energy between producers and consumers in aquatic ecosystems. Its decomposition by bacteria and fungi, along with limited utilization by zooplankton and the waste excreted by aquatic animals, releases stored energy, carbon, and nutrients, making them available again to primary producers and bacteria for metabolism. External sources of organic matter, such as wastewater discharges or runoff from agricultural lands, can increase microbial respiration and invertebrate production in aquatic ecosystems. Organic matter also affects the biological availability of minerals and elements and plays a significant protective role, as it influences the degree of light penetration in the water, which is crucial for the health of ecosystems.

Organic carbon

Organic carbon refers to countless organic compounds in the water. Dissolved organic carbon (DOC) is organic material from plants and animals that has been broken down into very small sizes, usually with a diameter of less than 0.45 μm. DOC originating from a drainage basin often consists of humic acids and can have a yellow or brown color, which can be detected in a water sample. DOC produced in situ is usually unpigmented, and the pigmentation of DOC that enters the system can be lost due to degradation by light. Waters with high DOC tend to have lower pH values.

* Scientific papers by Charles and Polia.

Biochemical oxygen demand and chemical oxygen demand

Many aquatic ecosystems heavily rely on external sources of organic matter to maintain their production. However, excessive input of organic matter from drainage basins, such as from wastewater discharges, can seriously disrupt the natural production balance of the aquatic system. This leads to excessive bacterial growth and increased consumption of dissolved oxygen, which can compromise the integrity of the ecosystem and create conditions for the proliferation of less ideal species, threatening biodiversity and ecosystem stability.

Biochemical oxygen demand (BOD)* and Chemical oxygen demand (COD)** are two common measures of water quality that reflect the degree of pollution with organic matter in a water body. Biochemical oxygen demand (BOD) represents a measure of the amount of oxygen removed from the water environment by aerobic microorganisms for their metabolism while decomposing organic matter. Systems with high BOD typically have low concentrations of dissolved oxygen, which can disrupt the balance of the ecosystem. Chemical oxygen demand (COD) represents a measure of the oxygen equivalent of organic matter in water that can be oxidized by strong chemical oxidants, such as dichromate (Chapman, 1996)***. Although the values of BOD and COD in clean water systems are often close to the detection limits, water samples near sources of organic matter pollution show very high values.

* DOC) - Dissolved organic carbon
** in situ means that it is created within the ecosystem itself, without being brought in from external sources
*** (BOD) - Biochemical Oxygen Demand
**** (COD) - Chemical oxygen demand
Scientific papers by Chapman, 1996.

7. Classification of Surface Waters According to Water Quality

According to the Directive on Water Classification, waters are classified into five classes based on their degree of purity and intended use:

1. First class: This is very clean, oligotrophic water that can be used for drinking with possible disinfection, as well as for the production and processing of food products. Waters of this class are suitable for spawning and rearing noble fish, such as salmonids. They have a high buffering capacity, oxygen saturation and a very low content of nutrients and bacteria.

2. Second class: Slightly polluted water (mesotrophic), which can be used for swimming, recreation, and water sports. It is suitable for rearing other fish species (cyprinids), and with common treatment (coagulation, filtration, disinfection), it can also be used for drinking. The oxygen saturation and buffering capacity are good throughout the year.

3. Third class: Moderately polluted water (eutrophic), which in its natural condition is suitable for irrigation. After appropriate treatment, it can also be used in industry where drinking water quality is not required. The buffering capacity is weak, but the pH values are still suitable for most fish. Changes in the structure of aquatic communities and variations in the concentration of harmful substances may occur.

4. Fourth Class: Highly eutrophic and polluted water that is used only after certain treatment for limited purposes. The water exhibits increased acidity, which negatively affects fish. In the hypolimnion, oxygen deficiency occurs, leading to anaerobic conditions that reduce biological productivity and cause algal “blooms”.

5. Fifth Class: This is highly polluted water (hypertrophic) that cannot be used for any purpose. The buffering capacity is completely lost, leading to high levels of acidity and the absence of fish life. The concentration of harmful substances is high and poses a danger to aquatic life, causing toxicity.

8. Research methodologyo

The methodology applied in this study encompassed a wide range of techniques and standardized procedures for accurately assessing the condition of the Treska River. A standardized procedure was employed for sampling at three different locations, which provided representative data on the water quality. The analysis included physical parameters such as temperature, color, turbidity, and flow rate, in order to determine the basic physical characteristics of the water. Furthermore, chemical analyses allowed for the identification of the presence of nutrients, metals, and other pollutants, evaluating the level of chemical contamination. The collected data underwent in-depth analysis and interpretation, enabling

* Научни написи на Chapman, 1996.

the identification of trends and assessment of the impact on the river ecosystem. Throughout all phases, rigorous quality control and assurance were implemented to ensure the accuracy and reliability of the results.

Sampling Procedure

Correct collection of water samples is crucial for the accuracy of physical-chemical analysis. At the outset, several strategic sampling points along the river were carefully selected in order to cover different sedimentation conditions, such as upstream, midstream and downstream, to ensure representativeness of water quality in different parts of the Treska River course. To ensure accurate data, samples were taken at different time intervals to account for natural variations in flow and water quality. Clean, sterilized dishes were used, and sterile gloves were used to avoid contamination. The samples were stored in appropriate conditions and transported to the laboratory within 24 hours.

This procedure was carried out in accordance with the standard for quality water sampling from rivers, according to EN ISO 5667 Part 6.

Првото мерно место е во Матка крајната станица на јавниот превоз под паркингот

Второто мерно место е во изпустниот канал од езерото Треска во река Треска.

Третото мерно место е во селото Крушопек пред соединување со реката Вардар.

Analysis of the Physical Properties of Water

Within the physical analyses of the water, several key parameters that affect water quality and the ecosystem in the Treska River were measured. First, the water temperature was measured, which plays a significant role in all chemical and biological processes. The temperature was directly measured on the field, as changes in it can influence the solubility of gases as well as the metabolism of aquatic organisms. Furthermore, the turbidity of the water was determined by measuring the presence of suspended particles. This parameter is important because higher turbidity levels can reduce the light reaching aquatic plants, thus negatively impacting photosynthesis and biodiversity.

Additionally, the flow rate of the water was measured, as it influences the transport of nutrients and pollutants throughout the riverbed. This parameter is important for assessing the movement of sediments and other materials that can alter the river habitat.

Additionally, electrical conductivity was measured to assess the concentration of dissolved ions in the water. Higher conductivity indicates the presence of salts and minerals, which can originate from natural sources or human activities, such as agriculture and industry. This parameter is important for determining the degree of water contamination with chemical substances.

Chemical analysis of water

When measuring the concentrations of nutrients such as nitrates (NO_3-), phosphates (PO_4^{3-}), and ammonium (NH_4^+), an accredited method using spectrophotometry was employed. These nutrients are important indicators of pollution, often caused by agricultural runoff or wastewater. Monitoring these parameters aids in assessing the impact of pollution on water quality and the health of the ecosystem.

For the assessment of chemical oxygen demand (COD), an accredited method for COD in surface waters was applied. This parameter indicates the amount of oxygen required to oxidize organic and inorganic substances in the water, which allows for the evaluation of pollution levels and the potential impact on living organisms.

For the biochemical oxygen demand (BOD), the samples were incubated at 20°C for a period of five days, after which the level of dissolved oxygen was measured. BOD indicates the amount of oxygen that microorganisms consume while decomposing organic matter and is an important indicator of organic pollution and the health of the aquatic ecosystem.

Total dissolved solids (TDS) were measured using an internal method. TDS represents the total amount of dissolved minerals and salts in the water, which is a key indicator of water quality and its suitability for various uses.

The alkalinity and hardness of the water were determined using an accredited method. These properties affect the water's ability to neutralize acids and its interaction with aquatic life. Monitoring these parameters is important for water safety and its suitability for ecosystems and human activities.

Dissolved oxygen (DO) was measured using a titration method, as it is essential for maintaining a healthy aquatic ecosystem. Low oxygen levels can cause stress or death in aquatic organisms due to pollution or other environmental factors.

The pH measurement was conducted using a calibrated pH meter to determine the acidity or alkalinity of the water. The pH value is a key factor for biological activity, as it affects the solubility of nutrients, toxic metals, and chemicals. Excessive acidity or alkalinity can be harmful to the aquatic ecosystem and can impact the environmental balance.

Data analysis and interpretation

- **Statistical methods:** Various statistical methods were applied to analyze the collected data, including calculation of standard deviation, mean values and correlations between different parameters. These techniques allowed the identification of relationships between water quality and various influencing factors, leading to deeper insight into their influence on the physical and chemical properties of water.
- **Comparison with standards:** To evaluate the obtained results, they were compared with national and international water quality standards, such as those set by the World Health Organization and the U.S. Environmental Protection Agency (EPA). This comparison helped identify potential pollution trends and assess the health of the aquatic ecosystem.
- **Assessment of results:** Appropriate evaluation of the results according to the established limit values for permissible pollution levels in the Republic of North Macedonia. Use of the Official Gazette* with the appropriate manual for the assessment and determination of surface waters.

https://www.moepp.gov.mk/wp-content/uploads/2014/09/Uredba%20za%20klasifikacija%20na%20vodite%20Sl.vesnik%2018

Quality control and assurance

- **Calibration of instruments:** All measuring devices used for the analyses were regularly calibrated before and after each use, as well as when necessary.
- **Control samples:** Control or check methods with known concentrations were used to accurately validate the laboratory analyses.
- **Minimizing errors:** Strict adherence to techniques and protocols for sample preservation and minimizing human errors during laboratory testing.

The Central Environmental Laboratory, which is part of the Ministry of Environment and Physical Planning, implements a methodology that provides a comprehensive framework for accurately assessing the physical and chemical characteristics of river waters, which is vital for evaluating water quality and identifying sources of pollution.

9. *Results and analysis of research results*

Documenting the condition of solid waste on the coast of the Treska River

During the field research, a significant number of dumpsites with various types of waste were observed, including household waste, bulky waste, and construction debris, which citizens not only throw beside the river but also directly into it. This improper practice seriously endangers the environment, as it not only pollutes the local landscape but also poses a direct threat to the aquatic life in the Treska River. The waste causes the death of aquatic organisms and disrupts the ecological balance, which can have long-term consequences for biodiversity in the region.

Additionally, throwing waste into the riverbed leads to its narrowing, which reduces water flow. This creates an increased risk of flooding, especially during heavy rainfalls when the river cannot channel large volumes of water. Such floods can cause significant damage to surrounding communities and infrastructure, posing a threat to the safety of people and their homes. This factual situation was documented through several photographs, which will serve as important evidence for the need to take urgent action. Through these documented examples, the urgency for better waste management and active protection of water resources is highlighted, which will include joint action by local authorities and the community to prevent further ecological disasters.

Improper disposal of electrical appliances
The picture shows refrigerators after the protective metal covers have been removed

Collected municipal and construction waste improperly discarded alongside the Treska River

Unsorted various waste from municipal sources. Tires, electrical appliances, plastics, nylon, sanitary items, etc

Results of the physical-chemical analyses conducted in the Central Environmental Laboratory

The results of the laboratory analyses are presented below, covering all tested parameters. The table shows the summarized data from the analyses of the three samples taken from different locations along the river. These results provide a detailed overview of the water quality and its physical-chemical properties at each of the tested points.

Results of the analysis of the samples taken from the Treska River

10.06.2024 Lab No.14-023/2024	1 measuring loca-tion, sample no. 10042	2 measuring location, sample no. 10043	3 measuring loca-tion, sample no. 10044
Parameter			
Temperature 0C	12	18	14
pH	8.04	8.42	8.35
Total hardness odH	15.5	14.5	13.5
Total dry residue mg/l	256	566	266
Dissolved solids mg/l	236	250	252
Suspended solids mg/l	20	316	14
COD(K2Cr207) mg/lO_2	125	16	7
BOD -5 mg/LO_2	25	9.57	4.18
Ammonia NH_4^+ mg/lN	10	0.17	0.56
Nitrates NO_3^-mg/lN	2	<0.8	<0.5
Phosphates PO_4^{3-} mg/lP	1	<0.8	<0.5

- pH (8.04 - 8.42): This range places the water in the first class according to the directive for water classification (Official Gazette 18/99), indicating alkaline conditions suitable for most aquatic organisms. The alkalinity of the water influences biological productivity and chemical processes.
- Total hardness (13.5 - 15.5): These values indicate the amount of calcium and magnesium in the water. Water with this hardness is moderately hard, which is typical for natural water systems. These elements are essential for organisms, but excessive hardness can cause difficulties in the existence of certain species.
- Total dry residue (256 - 566 mg/l): Water from two measuring locations falls into the first class, while water from the third measuring location falls into the second class. This parameter indicates the amount of inorganic and organic matter that remains after the evaporation of water, which can affect water quality and aquatic life.

- Dissolved solids (236 - 252 mg/l) encompass various inorganic and organic substances, such as minerals and salts, which are naturally found in water systems. Typically, these substances include calcium, magnesium, sodium, potassium, bicarbonates, sulfates, and chlorides, as well as smaller amounts of organic matter, such as humic acids. These components not only contribute to the mineral balance of the water but are also essential for the life of organisms in the aquatic environment. Values ranging from 236 to 252 mg/l indicate that the water contains moderate concentrations of these substances, which is characteristic of relatively clean waters, with good mineral content that supports ecologically healthy aquatic ecosystems.
- Suspended solids (14 - 316 mg/l): This parameter indicates that at one measuring location, the value reaches the fifth class of quality, which means there is a high concentration of suspended solids that can cloud the water and reduce the oxygen available for aquatic organisms.
- Chemical oxygen demand (7 - 125 mg/l): At one measuring location, this value places the water in the fifth class, indicating a high presence of decomposing organic matter that reduces dissolved oxygen. This process can lead to eutrophication, which is a negative process for aquatic ecosystems.
- Biochemical oxygen demand (4 - 25 mg/l): The values indicate the presence of bacteria, which means that the water may be contaminated with organic matter. The values in the fifth class indicate critical pollution.
- Ammonia (0.17 - 10 mg/l): Low ammonia values indicate a good condition of the water concerning this parameter, as ammonia can be toxic to aquatic organisms only at high concentrations.
- Nitrates (0.5 - 2 mg/l): Low nitrate levels place the water in the first class, indicating that there is no excessive pollution from agricultural activities or other sources of nitrogen compounds.
- Phosphates (0.5 - 1 mg/l): The water is classified as first class due to low phosphate levels, which usually originate from detergents and agricultural fertilizers. Specifically, the water is classified in the first class due to low phosphate levels (0.5-1 mg/l), indicating an absence of risk for eutrophication and uncontrolled algal growth.

Based on our field and laboratory research, we have concluded that the Treska River is significantly polluted as a result of anthropogenic influence, namely human activities. The pollution results from several factors, including improper disposal of solid waste and the presence of illegal dumpsites along the river, as well as the discharge of wastewater without any prior treatment. This particularly refers to small agricultural facilities that do not have treatment plants, as well as to municipal wastewater from households in the surrounding settlements. Additionally, the use of pesticides and synthetic fertilizers in agriculture significantly contributes to the degradation of water quality. The results obtained from our research, especially from the analysis of chemical and biochemical oxygen demand, prompted us to deepen the study and complement it with the latest results from bacteriological tests conducted by the Public Health Center - Skopje. These results are critically important because biological pollution can not only impact public health but also seriously threaten aquatic ecosystems by disrupting the balance of local biodiversity.

Specifically, the findings are essential for understanding the degree and nature of bacteriological pollution in the Treska River. These tests focus on the presence of pathogenic bacteria and their concentrations, which are a direct indicator of water quality, especially in the context of fecal pollution caused by wastewater and improper disposal of municipal waste. Including their results allows us to make an accurate assessment of the health risks associated with water use, as well as to understand the effects of untreated wastewater being discharged into the river. Bacteriological pollution is particularly important because it can affect public health, the ecological condition of the river, and threaten aquatic ecosystems, making the inclusion of their analyses a key component of our comprehensive assessment of the condition of the Treska River.

Results and interpretations of the condition of the Treska River obtained from the PHI Center for Public Health - Skopje

The PHI Center for Public Health - Skopje is an accredited laboratory by IARSM, EA MLA with certificate LT - 19, in accordance with the requirements of MKS ISO 17025/2006 for chemical and microbiological testing of food and water, as well as for sampling of food and water.

Surface water from the Treska River for May				
Measuring point	Treska River Recre-ational Center - Saraj	Treska River band	Treska River be-fore Talozhnik	Treska River under the dam of the lake Matka
	29.05.2023. Lab. No. 1289/203	31.05.2023. Lab. No. 1290/2023.	29.05.2023. Lab. No. 1288/2023.	31.05.2023. Lab. No. 1291/2023.
Parameter	Measured value			
Temperature °C	14	9	15	15
Color degrees Pt-Co	10	10	12	9
Odor at 25 degrees Celsius	/	/	/	/
Turbidity NTU > than	0.4	0.8	0.3	0.3
pH	8.3	8	7.8	8.3
Total residue from evaporation mg/L	229	268	217	223
Suspended solids mg/L	4	3	10	14
Dissolved Oxygen in mg/L	10.5	10.7	13.9	11.4
Oxygen concentration in %	101	92	137	112
Biochemical Oxygen Demand mg/L	1	0.8	3.7	0.8
Dry residue of filtered water mg/L	225	265	207	209
Chemical Oxygen Demand KMn mg/L oxygen	1.7	1.8	2.1	2.2
Nitrites as nitrogen μg/L	9	12	9	1.5
Nitrates as nitrogen μg/L	500	683	473	574
Chlorides mg/L	6.2	8.5	6.6	7.2
Ammonia as NH4 μg/L	25	50	50	50
Most probable number of coliform bacteria, number of bacteria /100 ml	> 500.000	> 500.000	> 100.000	> 500.000

Lab. No:	Expert Opinion:
1289/2023	The tested surface water sample CORRESPONDS to Class IV according to the Regulation on Water Classification (Official Gazette of the Republic of Macedonia No. 18/99) regarding the physical-chemical analysis, and ac-cording to the regulations for bacteriological analysis, it ALSO CORRE-SPONDS to Class IV.
Date of printing: 29.05.2023.	

Lab. No:	Expert Opinion:
1291/2023	The tested surface water sample CORRESPONDS to Class I according to the Regulation on Water Classification (Official Gazette of the Republic of Macedonia No. 18/99) regarding the physical-chemical analysis, and ac-cording to the regulations for bacteriological analysis, it CORRESPONDS to Class IV.
Date of printing: 31.05.2023.	

Lab. No:	Expert Opinion
1290/2023	The tested surface water sample CORRESPONDS to Class III according to the Regulation on Water Classification (Official Gazette of the Republic of Macedonia No. 18/99) regarding the physical-chemical analysis, and ac-cording to the regulations for bacteriological analysis, it CORRESPONDS to Class IV.
Date of printing: 31.05.2023.	

Lab. No:	Expert Opinion
1290/2023	The tested surface water sample CORRESPONDS to Class II according to the Regulation on Water Classification (Official Gazette of the Republic of Macedonia No. 18/99) regarding the physical-chemical analysis, and ac-cording to the regulations for bacteriological analysis, it CORRESPONDS to Class IV.
Date of printing: 31.05.2023.	

Surface water from the Treska River for July		
Measuring point	Treska River Recreational Center - Saraj	Treska River under the dam of the lake Matka
	29.07.2023. Lab. No. 1909/203	31.07.2023. Lab. No. 1908/2023.
Parameter	Measured value	
Temperature °C	17	16
Color degrees Pt-Co	18	6
Odor at 25 degrees Celsius	/	/
Turbidity NTU > than	0.3	0.1
pH	8.3	8.4
Total residue from evaporation mg/L	178	240
Suspended solids mg/L	2	27
Dissolved Oxygen in mg/L	9.5	9.3
Oxygen concentration in %	97	93
Biochemical Oxygen Demand mg/L	1.4	0.9
Dry residue of filtered water mg/L	176	213
Chemical Oxygen Demand KMn mg/L oxygen	1.3	1.7
Nitrites as nitrogen µg/L	1.5	1.5
Nitrates as nitrogen µg/L	1466	711
Chlorides mg/L	6.4	8.3
Ammonia as NH4 µg/L	150	400
Most probable number of coliform bacteria, number of bacteria /100 ml	> 500.000	> 500.000

Lab. No:	Expert Opinion:
1908/2023	The tested sample of surface water CORRESPONDS to Class II of the Di-rective on Water Classification (Official Gazette of the Republic of Mace-donia No. 18/99) in terms of physical-chemical analysis, and in terms of the regulations for bacteriological analysis, it CORRESPONDS to Class IV.
Date of printing: 29.07.2023.	

Lab. No::	Expert Opinion:
1909/2023	The tested surface water sample CORRESPONDS to Class II according to the Regulation on Water Classification (Official Gazette of the Republic of Macedonia No. 18/99) regarding the physical-chemical analysis, and according to the regulations for bacteriological analysis, it CORRESPONDS to Class IV.
Date of printing: 31.07.2023..	

Surface water from the Treska River for July				
Measuring point	Treska River Recrea-tional Center - Saraj	Treska River under the dam of the lake Matka	Treska River band	Treska River be-fore Talozhnik
	05.10.2023. Lab. No. 2560/2003	05.10.2023. Lab. No. 2557/2023.	12.10.2023 Lab. No. 2619	12.10.2023. Lab. No. 2621
Parameter	Measured value			
Temperature °C	17	16	14	17
Color degrees Pt-Co	7	7	7	21
Odor at 25 degrees Celsius	/	/	/	/
Turbidity NTU > than	0.3	0.2	0.4	0.2
pH	8.3	8	8.5	8.4
Total residue from evaporation mg/L	246	253	237	207
Suspended solids mg/L	34	52	16	13
Dissolved Oxygen in mg/L	9.5	10	9.8	9.7
Oxygen concentration in %	97	100	94	99
Biochemical Oxygen Demand mg/L	1.6	1.3	4.6	1.8
Dry residue of filtered water mg/L	212	201	221	194
Chemical Oxygen Demand KMn mg/L oxygen	1.6	1.9	1.9	1.9
Nitrites as nitrogen µg/L	н.д.	9	9	1.5
Nitrates as nitrogen µg/L	690	526	522	484
Chlorides mg/L	10	8.5	8.4	7.9
Ammonia as NH4 µg/L	25	н.д.	150	100
Most probable number of coliform bacteria, number of bacteria /100 ml	> 100000	> 100000	> 5000	> 100000

Lab. No:	Expert Opinion:
2557/2023	The tested surface water sample CORRESPONDS to Class III according to the Regulation on Water Classification (Official Gazette of the Republic of Macedonia No. 18/99) regarding the physical-chemical analysis, and ac-cording to the regulations for bacteriological analysis, it CORRESPONDS to Class IV.
Date of printing: 05.10.2023.	

Lab. No:	Expert Opinion:
2560/2023	The tested surface water sample CORRESPONDS to Class III according to the Regulation on Water Classification (Official Gazette of the Republic of Macedonia No. 18/99) for physical-chemical analysis, and CORRESPONDS to Class IV according to the regulations for bacteriological analysis.
Date of printing: 05.10.2023.	

Lab. No:	Expert Opinion:
2619/2023	The tested surface water sample COMPLIES with Class III according to the Regulation on Water Classification (Official Gazette of the Republic of Mace-donia No. 18/99) concerning physical-chemical analysis, and COMPLIES with Class IV according to the regulations for bacteriological analysis.
Date of printing: 12.10.2023.	

Lab. No:	Expert Opinion:
2621/2023	The tested surface water sample COMPLIES with Class II according to the Regulation on Water Classification (Official Gazette of the Republic of Mace-donia No. 18/99) concerning physical-chemical analysis, and COMPLIES with Class IV according to the regulations for bacteriological analysis.
Date of printing: 12.10.2023.	

Based on the conducted analyses, the results of the examinations of the surface water from the Treska River indicate significant pollution, especially in terms of the bacteriological parameters. According to the Directive on Water Classification (Official Gazette of the Republic of Macedonia No. 18/99), the water samples in terms of physical-chemical analysis correspond to Class II or III, indicating several levels of quality. However, the analyses for bacteriological parameters show that the water falls into Class IV, resulting from contamination with fecal matter, confirmed by the presence of pathogenic bacteria such as Escherichia coli and coliform bacteria. These results are in accordance with the legal and professional regulations for the quality of river water, meaning that the Treska River is unsuitable for any use, including recreation or irrigation. The systematic presence of fecal bacteria indicates serious ecological and health risks, requiring urgent measures for management and improvement of water quality. Increased concentrations of chemical pollutants further complicate the situation, indicating that this water is unsafe for any purpose. Given this condition, our research further confirms the importance of continuous monitoring and documentation of water quality in the Treska River to protect and improve the ecological condition and health of the local population.

10. Conclusion

„Caring for the waters is not solely the responsibility of the state and institutions; it is the responsibility of each of us, as we are all part of the common space in which we live.“

Based on **the conducted research, which included field and laboratory analyses**, we can **conclude that the Treska River is in a serious danger due to long-term pollution and negligent anthropogenic activity**. The laboratory results from the physical-chemical and bacteriological analyses, conducted by our research team and the Institute of Public Health, show that the **water is classified between Class II and III according to the physical-chemical parameters**. This indicates a mesotrophic condition of the river, which can be used for swimming, recreation, and water sports, up to eutrophic condition suitable for irrigation but only after appropriate treatment and it also indicates that the water can be used in industry, where drinking quality is not required.

The biggest challenge remains the high bacteriological pollution, which places the river water in Class IV due to the presence of pathogenic bacteria of fecal origin, such as Escherichia coli and coliform bacteria. This makes the water particularly risky for any use without appropriate treatment, posing a significant threat to the health of the local population. The presence of these pathogens indicates serious contamination from sewage and municipal wastewater, which not only jeopardizes human health but also the entire ecosystem of the river. Additionally, analyses show that the high values of biochemical oxygen demand (BOD) and chemical oxygen demand (COD) indicate a significant presence of organic matter

Picture of the confluence of the Treska Lake into the Treska River.

and pollutants that burden the aquatic ecosystem. Systems with high BOD have reduced concentrations of dissolved oxygen, further endangering the aquatic life and diminishing the river's ability to self-purify. **The reduced oxygen level in the water not only hinder the life of aquatic organisms but also deteriorate the overall health of the ecosystem**. At the same time, the results from COD show high levels of oxidizable organic matter, indicating chemical pollution from industrial and agricultural sources. These parameters worsen the condition of the river, making it unsuitable for use.

Namely, the chemical analyses allow the river to be classified between Class II and III, which means it can be used for swimming, recreation, and water sports, up to an eutrophic condition suitable for irrigation after appropriate treatment, and even in industrial processes where drinking quality water is not required, however, **the bacteriological pollution, especially the presence of coliform bacteria, poses a serious obstacle**. Such bacteriological contamination complicates the use of the water for any activities without prior remediation of the pollution sources and its treatment. **The river remains unsafe for use without these steps, thereby continuing to jeopardize both the health of the population and the survival of endemic species in the aquatic ecosystem.**

The irresponsible behavior of the citizens, throwing and dumping of waste, and the discharge of untreated industrial and municipal wastewater significantly reduce the river's natural ability to self-purify. This long-term continuous pollution has negative consequences on the flora and fauna, resulting in the recent extinction of certain species, changes in biodiversity, and serious disruption of the ecosystem. **If uncontrolled pollution continues on this upward trend, the Treska River may permanently lose its ecological balance, especially the endemic species that survive solely in its waters.**

11. Recommendations for protection and improvement of water quality in the Treska River

In the context of increasing concern about the pollution of water resources in the Republic of North Macedonia, especially the Treska River, the need for specific measures for the protection and restoration of this significant ecosystem is becoming more urgent. Pollution from industrial, agricultural, and municipal sources not only disrupts water quality but also affects the environment and the health of the local population. The following are recommendations for improving the situation in order to preserve the Treska River and its natural resources.

1. **Strengthening the wastewater treatment infrastructure** - It is necessary to increase the number of wastewater treatment plants in areas with insufficient or nonexistent treatment systems. This includes the construction of new plants in rural and urban centers, especially in areas populated near the river, where there is a high level of pollution.

- Improvement of existing systems: Modernization of existing treatment plants through the application of new technologies that will effectively remove harmful substances and microorganisms.
- Separation of sewage and atmospheric water: Establishing systems for separating sewage and atmospheric water to prevent overflow and contamination of river water. These systems should include more efficient networks and structures for managing rainwater.
- Reconstruction of the infrastructure: Reconstruction of old and inefficient parts of the treatment system, as well as regular maintenance of existing plants to ensure their functionality and efficiency.

2. **Upgrade of waste management systems** - For effective management of water pollution and the protection of natural resources, it is essential to formalize the waste management practices, including recycling and the safe disposal of construction and hazardous waste. This recommendation includes:

- Formalizing the recycling practices: Introducing systems for the collection and selective recycling of waste, which will encourage citizens and companies to participate in the process. Local municipalities should establish recycling programs that are easily accessible to everyone and also organize educational campaigns to raise awareness about the importance of recycling.
- Systems for the disposal of construction and hazardous waste: Development of specialized methods for the disposal of construction waste, as well as the identification and treatment of hazardous waste. It is important to establish appropriate mechanisms for the transportation and treatment of this type of waste to prevent its contamination of water and soil.

- Improvement of waste management by local municipalities: Ensuring that local municipalities have adequate capacities and resources for proper waste handling. This includes training staff and developing infrastructure for the collection and treatment of waste to minimize the risk of illegal dumping.
- Prevention of illegal dumping: Implementing strict monitoring and punitive measures for illegal waste dumping, especially near the Treska River. These measures should include intensifying inspections and creating channels for citizens to report illegal dumping.
- Investing in infrastructure: Improving the waste management infrastructure, including the construction of new landfills and recycling centers, which will enable efficient and safe handling of various types of waste.
- Collaboration with the private sector: Encouraging collaboration with the private sector for the development of innovations in waste management, such as new technologies for recycling and hazardous waste treatment, which will help increase the efficiency of waste management systems.

3. **Modernization of public services** - To achieve effective management of sewage and wastewater, it is necessary to enhance the capacities of public utility companies and improve their resources. This recommendation includes:

- Increasing the capacities of public utility companies: This involves investing in staff training, increasing the number of employees, and enhancing the techniques and methodologies for wastewater management. By improving human resources, utility companies will be better prepared to deal with the challenges related to water pollution.
- Investing in new technologies: Establishing innovations and new technologies for monitoring and controlling the quality of wastewater. These technologies can help to track and manage discharges in real time and identify potential sources of pollution.
- Improving resources for sewage management: Obtaining sufficient funds for the procurement of equipment and tools necessary for effective management of wastewater systems. This includes investments in vehicles for waste collection and transportation, as well as in equipment for the maintenance and repair of sewage systems.
- Creating feedback systems: Establishing mechanisms for citizens to report issues, such as blocked sewage systems or unpleasant odors. This will help in identifying problems on the field and enable a quick response from utility services.
- Continuous monitoring and evaluation: Establishing systems for continuous monitoring and evaluation of the effectiveness of utility services to identify weaknesses and develop improvement strategies. This data can be used for planning future investments and improvements in the infrastructure

4. **Promoting sustainable agricultural practices -** To reduce the impact of agriculture and livestock farming on the environment, it is necessary to introduce sustainable practices in waste management from these activities. This includes:

- Application of ecological soil cultivation methods: Utilizing organic fertilizers, crop rotation, and integrated pest management to minimize chemical emissions into the environment and enhance soil health.

- Waste management in livestock farming: Establishing systems for the collection and processing of animal waste, such as composting, to minimize methane emissions and water pollution. The waste can be used as natural fertilizer instead of being discarded into the environment.
- Education for farmers: Organizing seminars and training for farmers on sustainable practices, including chemical management and resource optimization. Knowledge about sustainable agriculture will encourage farmers to adopt practices that help protect the environment.
- Financial support: Providing financial incentives and subsidies for farmers who implement sustainable practices, such as organic farming and sustainable livestock management. This can include tax reductions or reimbursements for purchasing eco-friendly tools and materials.

5. **Strengthening of the public awareness and greater citizen involvement -** To encourage community involvement in pollution prevention, it is necessary to increase public awareness of the importance of proper waste management and environmental protection. This can be achieved through:

- Awareness-raising campaigns: Organizing informative campaigns for the public, focused on the impact of pollution on health and the environment. The campaigns can include various media, including television, electronic media, radio, and social networks.
- Engaging the local community: Introducing programs for citizen participation in initiatives to clean the Treska River and organizing workshops on proper waste management. These activities will encourage citizens to actively engage in environmental protection.
- Involvement of educational institutions: Development of educational programs for schools that will include topics on environmental protection and sustainable waste management. This will help raise a new generation of conscious citizens.

6. **Implementation of stricter regulations** - To prevent pollution, it is necessary to implement stricter regulations and penalties for illegal disposal of municipal waste. This includes:

- Strict penalties for violators: Establishing legal provisions that impose high penalties on individuals and companies that illegally dispose of waste or violate waste management regulations. This measure should have a deterrent effect and reduce the number of violations.
- Checks and inspections: Introducing regular inspections of public and private waste management spaces to ensure compliance with legal regulations. Inspectors should be equipped with adequate powers to punish violators.
- Eliminating practices such as waste burning: Development of campaigns to raise awareness of the dangers of waste burning and setting up controls to detect such activities. Conduct regular inspections and penalties for those who practice this method.

7. **Establishment of an effective monitoring system** The issues with water monitoring in the Republic of North Macedonia, particularly in the context of a lack of regulations and resources, create significant challenges for the sustainable management of water resources. Below are several key recommendations for improving the water quality monitoring system:

- Establishing clear legal provisions: The Ministry of Environment and Physical Planning should adopt by-laws related to the establishment and maintenance of the water monitoring system.
- Improvement of the hydrological monitoring network: The Government of the Republic of North Macedonia needs to invest in the modernization of the hydrological monitoring network, with an emphasis on new measuring stations and modern equipment for accurate data collection and analysis.
- Clear definition of institutional competences: The roles and responsibilities of the relevant institutions, especially the Hydrometeorological Administration, must be precisely defined in the water laws and regulations.
- Regular budget for maintenance and development of monitoring: A stable and long-term financial plan is needed for the maintenance of the hydrological monitoring network and the establishment of new stations.
- Data availability and transparency: Data collected from monitoring should be available to inspection authorities, institutions and the public through a digital platform that will ensure transparency.
- Modernization of laboratories: Modern equipment is needed for water quality analysis laboratories, in order to monitor anthropogenic influences, such as waste and pesticides.

We believe that through this research we will contribute to the creation of a more sustainable and more efficient water resource management system, which will ensure the long-term protection of ecosystems. The recommendations we propose in this publication are primarily aimed at the relevant authorities and institutions, but they do not exclude citizens and civil society, who, through their active involvement, can significantly contribute to the protection and restoration of the Treska River, as well as all other water resources. With joint efforts, institutions and the community can create a sustainable and healthy environment for present and future generations

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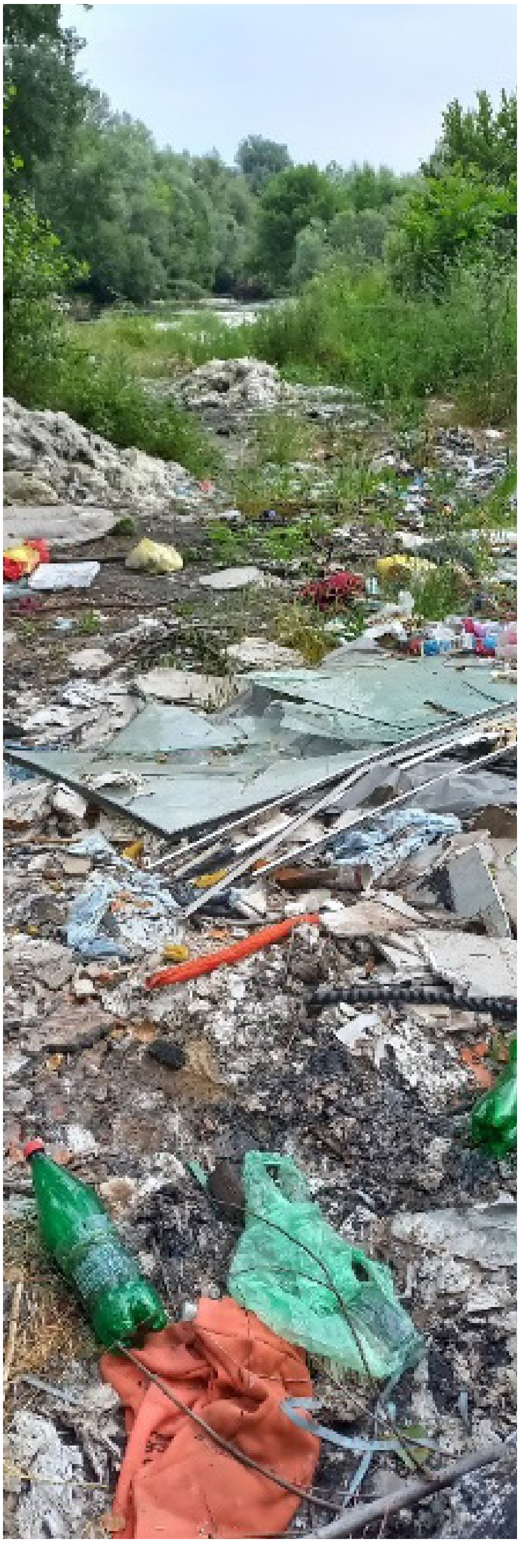
Appendices



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