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**BATHING WATER QUALITY**

**IN SLOVENIA**

HYDROSPHERE - GLOBE

Research paper

Authors: Aljaž Starič

Maša Šijanec

Julija Zver

Zala Jenko

Mentor: Nika Cebin

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***POVZETEK***

Naša raziskovalna naloga se osredotoča na analizo fizikalnih in kemijskih pokazateljev kakovosti vode. Za proučevanje smo si izbrali štiri vodna telesa, med njimi tri stoječe in eno tekočo vodo. Raziskovali smo vodo v Kočevskem, Podpeškem in Bloškem jezeru ter v reki Savi.

Cilj naloge je bil s pomočjo analize različnih parametrov lastnosti vode določiti, ali voda ustreza zahtevanim standardom za kopanje in rekreacijo ter ali je varna za zdravje ljudi. Merili smo pH in temperature vode ter s pomočjo reagentov določali koncentracijo različnih ionov. Vse te vrednosti so pomemben pokazatelj kakovosti vode, ki nam lahko pove ali je voda primerna za kopanje.

KLJUČNE BESEDE: naravna kopališča, ioni, reagenti, vodni krog, hidrologija, ionska kromatografija, analiza

***ABSTRACT***

Our research work focuses on the analysis of physical and chemical indicators of water quality. We analyzed water from four different locations, including three lakes and one river. We researched the water in Kočevsko jezero, Podpeškojezero and Bloško jezero and in the river Sava.

The goal of our assignment was to determine whether the water meets the required standards for swimming and recreation and whether it is safe for human health by analyzing various parameters of water properties. We measured the pH and temperature of the water and determined the concentration of various ions with the help of reagents. All these values ​​are important indicators of water quality, which can tell us whether the water is suitable for swimming.

KEY WORDS: natural bathing areas, ions, reagents, water cycle, hydrology, ion chromatography, analysis

# INTRODUCTION

As we enjoy swimming in natural swimming pools in the summer, we were therefore interested in their quality. We decided to investigate the quality of nearby natural bathing waters. We chose lakes Bloke, Kočevje and Podpeč, as well as two parts of the river Sava (Tomačevo and Savska beach) as the subject of study. We were interested in whether stagnant water (lakes) or flowing water (rivers) are more suitable for swimming.

Water is one of the most precious resources this planet has to offer. It is necessary for the life and functioning of all living beings in the world. However, we do not know how to use water properly and we are quickly running out of it. This is where knowledge from hydrology comes in handy, as it is the science that deals with all water bodies around the world. Hydrology deals with both the circulation of water and its flow.

The water cycle is the continuous circulation of water in the Earth's hydrosphere. It is accompanied by water that evaporates from the earth's surface, forms clouds and returns to the earth's surface as precipitation. The sun's radiation causes the circulation of water, so that water passes into the atmosphere in the form of water vapour. Water evaporates from glaciers, snow, ponds, lakes, seas and oceans. This evaporated water condenses when it cools with the help of rising air masses and turns into fog or dew and forms clouds. With precipitation (rain, hail, snow), the water cycle is completed.

Only 1% of all water on Earth is fresh inland water. They are found all over the world and are the main source of drinking water. They can occur naturally or be the result of human activity. Inland waters are divided into stagnant and flowing waters. Microorganisms play an important role in standing waters. Larger plants, especially algae, often thrive at the bottom of standing waters. Standing waters are important for the reproduction of amphibians and insects as well.

Since water is disappearing quickly, there is also a hydrology of pollution. It is a branch of hydrology, which is, among other sciences, part of geophysics. It deals with water quality, storage, disposal and spreading of pollution in water. In this research paper, the focus is on the quality of bathing water.

Objectives of the research paper:

* Use GLOBE hydrosphere protocols to determine whether there are significant differences in the chemical and biological properties of standing and flowing Slovenian bathing waters.
* Determine the quality of Slovenian bathing waters according to the results.
* Identify the factors that make bathing water better.

# THEORETICAL PART/REVIEW OF PUBLICATIONS

## DESCRIPTION OF NATURAL BATHING WATERS

### SAVA

Sava is a river in Central and South-Eastern Europe, a right tributary of the Danube, and the longest river in Slovenia. Sava river basin lies entirely within Slovenia, with more than half of the country's territory falling within its catchment area. It has two upstream branches, but we usually consider Sava Dolinka as its main branch. It rises in Zelenci near Podkoren, flows east and south-east and joins the Sava Bohinjka, which flows from Lake Bohinj, below Radovljica. The merged river continues its course through the Ljubljana basin, passes through the Posavje hills in a narrow gorge, crosses the Krško basin and enters the Pannonian Plain below Brežice. The difference in altitude between the river Sava and the wide bottom of the Ljubljana basin is about 90 m at Radovljica and only about 20 m at Ljubljana.

Both catchments of the Sava have an alpine snow-rain regime with a first peak in June and a second peak in October due to autumn rains and reduced evapotranspiration. The lowest flows occur in February, when precipitation remains mostly as a snow cover in the basin, with a second low in August. From Ljubljana downwards, the river has an alpine rain-snow regime, with the autumn rainfall peak prevailing over the snow peak.

Figure 1: The beach on the river Sava today.

Sava is a distinct torrent in its upper and middle reaches. It does not flood much in the Ljubljana basin either, as it mostly flows through a narrow and sparsely populated valley.

Even in the 90s of the last century, Sava was one of the most polluted rivers in Slovenia, with the exception of the upstream parts of the Sava Bohinjka and Sava Dolinka. It was mainly burdened by industry and cities, which at that time did not even have a sewage system. The water had increased levels of heavy metals. Until Ljubljana had a sewage treatment plant, Sava below its Ljubljanica outflow was in the worst quality class, and the same was true in Zasavje, where it received discharges from mines, industry and the city's sewage system. Bacteriological pollution was particularly damaging, so that nearly the entire course of the Sava was unsuitable for swimming.



Figure 2: Sava in the past.

Today's conditions are incomparable to those at that time. In 2010, the chemical state of Sava in its entire course through Slovenia was good, and the ecological state of the river was good to very good, with the exception of a few shorter sections, where the state was assessed as moderate.

The first hydroelectric power plant on Sava was built in 1955 (HE Moste), with the planned chain of hydroelectric power plants still being built. The Sava has much less water than the Drava, so there are fewer power plants.

Since ancient times, the river Sava has been an important transport route between south-eastern and central Europe. An old Greek tale speaks of the journey of the Argonauts from the Black Sea along the Danube, Sava and Ljubljanica to Vrhnika. Freight traffic on the river was maintained throughout the Middle Ages, but in the modern era the river became even more important for supplying troops in the wars with Turkey. After the Austrian army conquered Belgrade in 1717 and signed the Treaty of Požarevac with Turkey in 1718, trade with the newly conquered lands flourished. In 1735, the Austrian army started extensive regulation works, especially on the sections with dangerous rapids. For most of the way up the river from Brežice, goods were transported by draught cattle, for which a special towpath was built along the river. Traffic on the river ceased only with the construction of the southern railway (1849) and the Zidani Most-Sisak railway (1862).

Today, the waterway is not open for regular navigation and traffic on the river is only allowed during the day.



Figure 3: Sports on the Sava.

In some sections, Sava is important for sports and recreation. The most famous is the artificial kayak and canoe course in Tacno under Šmarna Gora, where the World Cup in kayaking and canoeing on wild waters is held. The upper reaches of the Sava up to Kranj are interesting for water sports, and Lake Trboje and Lake Zbilje for recreational activities.

(Source 1, Source 2)

### LAKE PODPEČ

Lake Podpeč or Lake Krim is a karst lake by the village of Jezero near Podpeč in the municipality of Brezovica. It lies at an altitude of 289 m. It is located on the southern edge of the Ljubljana marshes and receives water from seven surface karst springs. The peculiarity of the lake is the funnel-shaped underground drain, through which a narrow deep chasm leads, so far explored to a depth of 51 meters.



Figure 4: Lake Podpeč in winter.

Thus, Podpeč is one of the deepest lakes in Slovenia. The water flows through this funnel into the Hrušje stream, 300 m away, which is a right tributary of the Ljubljanica. The flat bottom, with the exception of the funnel, is otherwise at an average depth of 10 m. The lake has an area of about 1.2 ha, its shore forms an almost perfect circle with a diameter of about 130 m. The lake and the surrounding wetland plain have been declared a natural monument of Slovenia. The ecosystem of the lake is formed by many plant and animal species, aquatic inhabitants are crayfish, various river mussels and fish (pike, perch, chub, catfish, etc.).



Figure 5 : Lake Podpeč in summer.

There is a small swimming area around the lake, and fishing is also possible in the lake. The lake has 3 piers as well.

(Source 3, Source 4)

### LAKE KOČEVJE

Lake Kočevje is located in Kočevsko polje, in the northeastern part of Kočevje. It lies at an altitude of 471 meters. It is an artificial, non-flowing lake that was created as a result of the operation of the mine. It is considered one of the cleanest and deepest lakes in Slovenia. It was formed at the bottom of a mine basin where brown coal was mined. During the mine's operation, the Rudnik stream flowed into the mine basin, filling two large puddles, whose water was pumped out and used for coal separation during the mine's operation. The water was drained into the nearby river Rinža through large pipes. In 1978, work in the mine stopped, and water slowly filled the basin. The lake is up to 36 m deep, its area is about 39 ha, and the coast is about 3 km long.



Figure 6 : Lake Kočevje from a bird's eye view.

There is a nature trail around the lake. Today, the lake offers many recreational opportunities; boating, swimming, diving, and skating in winter. More recently, fish have been artificially introduced into the lake. There are chubs, tench, carp, catfish, redfin, pike, grass carp, etc. in the lake. Fishing is possible in the lake with a permit.



Figure 7: Lake Kočevje.

The lake's surroundings are inhabited by various species of plants and animals, and the lake is nesting ground for many species of birds, many of which are listed on the "Red List" of endangered nesting birds in Slovenia. On the northernmost side of the lake area is a pine forest, a habitat peculiar to Kočevje. Birch trees grow on the shores of the lake.

(Source 5, Source 6)

### LAKE BLOKE

HISTORY

There are no organised papers or plans about the creation of today's lake. According to oral testimony and memories of older residents of Volčje, a stream flowed from the springs below Ogrnik and Suhi hill through a hole in the ancient embankment. The lake is said to have been made by the locals around 1964 or 1965. Trees were still growing out of the water at that time. In the first year, the lake was drained in autumn, and in the second year it was mowed and harvested again. The water in the lake was clean, and you could feel the freshly cut grass on the ground. In the following years, the water was no longer released and the stream flowed over the dam again into the Bloščica. The Tourist Board was ensuring that excursionists slowly started to arrive on the lake. Bathers in the summer, and after the settlement of carp, chub and redfin, fishermen as well. After 1970, the first holiday cottages began to spring up on the slopes of Ogrnik. An annual refreshment stand was set up by the lake. The lake began to become overgrown, covered with aquatic vegetation that wrapped itself around the feet of bathers. The bottom was slowly turning to silt and the lake was getting less and less water. In 2003, the municipality of Bloke drained the lake and redeveloped the surrounding area, bottom of the lake, and ducks and other water birds got their own small island. They built a new dam and entrances to the lake for bathers. Fish were artificially introduced into the lake, and other animals came into the lake from the surrounding area. Mallards are present for most of the year, and in the spring and autumn, migratory birds stop on the shores of the lake. Water lilies bloom on the surface of the water in the summer months.

Figure 8: Lake Bloke in the past.

TODAY

Lake Bloke is man-made and is 0.8 hectares in size and up to 3 meters deep. It is filled by the waters of the Bloščice stream, 2 springs flow into it, and one smaller spring is at the very bottom of the lake. The lake is somewhat triangular. It is the largest surface water on the Bloke plateau and lies at an altitude of 748 meters above sea level. The water temperature reaches 26 °C in summer.

Figure 9: Lake Bloke today.

These days, the lake is a very popular tourist destination. The lake is frequented by swimmers in summer and ice skaters in winter. Fishing is present all year round, and has expanded, especially with the introduction of carp into the lake. In addition to carp, the lake is home to native species such as minnows, brook crayfish, lake mussels and gudgeons.

(source 7, source8, source 9, source 10, source 11, source 12, source 13, source 14, source 15, source 16)

## HYDROLOGY

### HYDROLOGY IN GENERAL

Water is a very important and valuable commodity. It is key to life and our functioning. We need to take great care in preserving water for our future, and so a science has been developed to study the state of the world's waters. (source 17)



Hydrology, alternatively known as water science, is the physical geographic study of water bodies. Hydrology studies the movement, distribution and quality of water throughout the world. Hydrology is the study of both surface water and groundwater, and the circulation and properties of water in nature.

(source 18)

Figure 10: Sava River.

Slovenia consists of four main river basins. The largest is the Sava basin. The Sava basin includes Upper Carniola, Lower Carniola and Inner Carniola, which takes up about half of the whole of Slovenia. The next basin is the Drava basin. It covers a large part of Styria and Carinthia. Then comes the Mur basin, which includes Prekmurje and the northeastern part of Styria. Last but not least is the Soča basin. This basin covers a large part of Littoral. Southwest Slovenia does not belong to any of these four basins, as the rivers of this area flow into the Adriatic Sea.

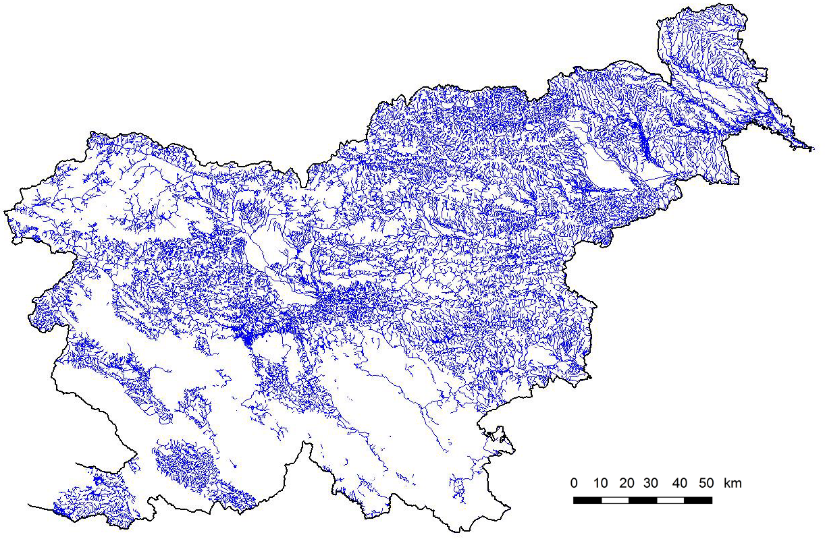


Figure 11: Water bodies in Slovenia.

Slovenia is the richest European country in terms of the amount of river water per inhabitant. Pollution is a major problem in Slovenia's rivers. These are polluted due to industry and agriculture located near them. Slovenia's rivers have great energy potential, especially the Drava, but this potential is not being harnessed to its full potential in the country.

Much of Slovenia's water is underground, i.e. it is groundwater. This is very evident in the Karst, where surface water and groundwater are very well connected.

(Source 19)

#### ARSO

Hydrology is the subject of national hydrological services around the world. In Slovenia, hydrology is dealt with by the ARSO (Slovenian Environment Agency). ARSO assesses the likelihood of severe weather and hydrological events and their impact on people and their quality of life.

(Source 20)



Figure 12: Logo of the Slovenian Environment Agency.

ARSO's tasks in relation to hydrology are:

* analysis and forecasting of hydrological conditions, including forecasts of adverse and severe hydrological conditions,
* analysis and prediction of the water balance,
* assessment and forecast of the quantitative state of water and assessment of available water resources,
* monitoring changes in all elements of the hydrological cycle.

ANALYSIS AND FORECAST OF HYDROLOGICAL CONDITIONS

Hydrological conditions are measured using the following parameters:

* water level (the height of the water surface),
* flow rate,
* water temperature,
* the content of toxic substances,
* water turbidity,
* sea level,
* sea temperature,
* sea waves,
* sea current.

(Source 21)

ANALYSIS AND FORECAST OF THE WATER BALANCE

The water balance is used to determine the state of the water. (Source 22)

The water balance is affected by:

* amount of precipitation,
* surface ground inflows and outflows,
* evapotranspiration (movement of water from the Earth's surface into the atmosphere), (source 23)
* change in soil water supply.

ASSESSMENT AND FORECAST OF THE QUANTITATIVE STATE OF WATER AND WATER RESOURCES

The status of surface water and water resources is determined on the basis of the Surface Water Ordinance.

(Source 24)

Surface water quality is affected by:

* chemical state,
* ecological condition,
* ecological potential of artificially formed water bodies.

The status of groundwater and water resources is determined on the basis of the Groundwater Regulation. (Source 25)

Groundwater quality is affected by:

* chemical state,
* quantity status,
* water source load.

CHANGES IN THE ELEMENTS OF THE HYDROLOGICAL CYCLE

The biggest change to the hydrological cycle is global warming, which brings climate change. ARSO monitors all climate changes and their impact on water conditions in Slovenia.

### THE WATER CYCLE IN NATURE

The water cycle is the continuous circulation of water in the Earth's hydrosphere. The water cycle is a biogeochemical cycle (flow of water above and below the ground). It is a key element of other biogeochemical cycles. The water cycle describes the processes that move water through the hydrosphere. Much water is stored for longer periods of time than it travels through the water cycle. Most of the water on Earth is stored in the oceans. During colder periods, more glaciers form to store water that should be travelling in the water cycle, thus reducing the amount of water in other parts of the water cycle. In warm periods, it's the other way around. Glaciers are melting, so more water is available to travel in the water cycle.

Humans influence the water cycle too. The water cycle is affected by agriculture, industry, construction of dams, deforestation and afforestation, withdrawal of water from rivers, urbanisation and changes in the chemical composition of the atmosphere.

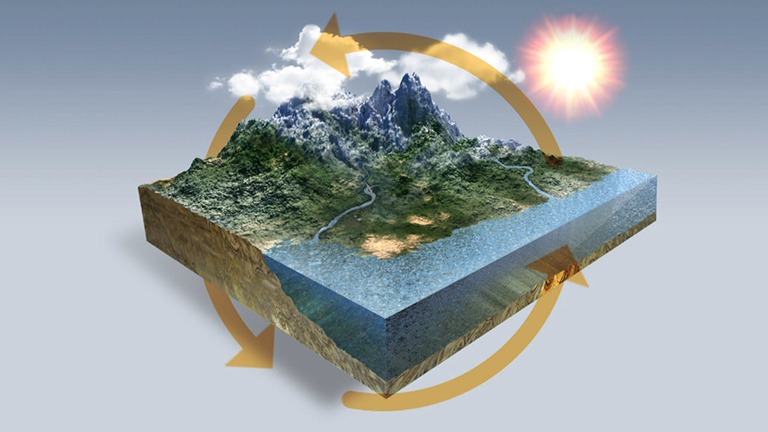


Figure 13: Water circulation.

THE WATER CYCLE DESCRIPTION

The sun heats the water in the oceans and other surface water bodies. Water evaporates (evaporation is the transformation of water from a liquid to a gaseous aggregate state and the movement of water from bodies of water into the atmosphere) as water vapour in the air, while ice and snow can sublimate directly into water vapour. About 90% of the world's water evaporation comes from the oceans, which cover a large part of the earth's surface. Water vapor is released into the air by transpiration (the release of water vapor from plants into the air).

Rising air currents can lift water vapor into the atmosphere, where cooler temperatures cause water vapor to condense into clouds. Water vapor in the air is therefore raised by convection, which means that warm, moist air will rise while cooler, dry air will flow downwards. As warmer air rises, the air loses energy, which causes its temperature to drop, so water vapor changes its aggregate state to liquid or ice.

Clouds move around the world with air currents and when they collide with each other or grow together, they fall from the sky as precipitation. They start when water vapor that has been condensed in the atmosphere becomes too heavy to stay in atmospheric air currents.

Precipitation is condensed water vapour that falls on the Earth's surface. Some precipitation falls as snow or hail, most is rain. Water can accumulate in ice and glaciers, where it freezes and can be stored for thousands of years. Most water falls into the oceans or onto land. Precipitation that reaches the surface of the Earth, but does not penetrate the ground, is called runoff.

When there is high rainfall and the soil is already sufficiently saturated with water, additional precipitation can no longer penetrate the soil. Part of the excess water that the earth cannot absorb, flows into valleys and rivers. Surface water always travels towards the lowest possible point, usually in the oceans. Some of the water is evaporated again, some seeps into the ground, or is used for agricultural, industrial or drinking water purposes.

Surplus water and groundwater are stored as fresh water in lakes. Some of these waters penetrate deep into the ground and recharge aquifers, storing fresh water for a long time. Part of the precipitation that reaches the earth's surface penetrates into the soil and this process is called infiltration. The amount of water that infiltrates into the soil varies according to the degree of slope of the terrain, the amount and type of vegetation, the type of soil and rock, and the water saturation of the soil. Other waters stay close to the surface and seep back into surface water bodies. Groundwater returns to the surface (through depletion) or eventually seeps into the oceans.

Water returns to the Earth's surface at a lower altitude from where it entered the ground due to gravity. Groundwater flows and refills slowly, and can remain in streams for thousands of years. Groundwater can be accessed by drilling or piping, or it can emerge as a freshwater source. Eventually, all of the water returns to the seas or oceans, where the water cycle actually begins.

(Source 26)



Figure 14: The flow of water in nature.

### COMPARISON OF FLOWING AND STANDING WATERS

#### STANDING WATERS

Standing waters are distinguished as ponds or marshes, wetlands and lakes.

A pond or marsh is a small basin filled with stagnant water. It is usually smaller than a lake and larger than a swamp. They are often made artificially, for breeding fish or for the aesthetic decoration of the landscape. The ecosystem in the pond is most often enclosed.



Figure 15: Pond.

A wetland is a very small and shallow stagnant body of water. The amount of water in it fluctuates throughout the year, and during the summer it is often empty, as it is usually filled by rainwater. Wetlands are an important ecosystem for amphibians, especially frogs. They are home to dragonflies and other insects, as well as turtles, grass snakes and other animals. Unlike lakes and ponds, the wetlands are not home to fish.



Figure 16: Wetland.

The lake (Podpeč, Kočevje and Bloke) is a basin that is filled with water. It is bigger than lakes and ponds. These are permanent water catchments with typical stagnant water, with slow exchange. Lakes are divided according to their origin. We know natural and artificial lakes.



Figure 17: Lake Bled.

Natural lakes are the result of transformative processes on the Earth's surface that were not influenced by man.

1. TECTONIC LAKES are formed by the process of subsidence of the Earth's surface, when a deep basin is formed and filled with water.
2. FIRE OR VOLCANIC LAKES are formed in the craters of extinct volcanoes, so they are often round in shape.
3. GLACIER LAKES are formed by the action of a glacier. A glacier, which carves away the material in front of it, leaves behind basins and moraines in which lakes form.
4. NATURAL DAM LAKES are formed behind barriers created by landslides into a river valley or behind natural dams (beavers).
5. INTERMITTENT LAKES are karst lakes that fill with water during the rainy and snowmelt seasons and dry out during the dry season due to surface and groundwater runoff.

Artificial lakes were created due to human activity and as a result of economic activities. Most often, they are caused by dams, behind hydroelectric plants. These lakes are often used for irrigation or as a source of drinking water. A special example of artificial lakes are those created by subsidence above abandoned mines (Lake Kočevje).

Depending on the flow, we distinguish two types of lakes; flowing and non-flowing. Flowing lakes are characterized by having a constant above-ground inflow and outflow of water, while non-flowing lakes do not.

#### FLOWING WATERS

Flowing waters are waters that, due to their flow and velocity, can cause erosion and reshape the land surface. This creates a special type of relief - a river relief, which is characterized by gorges cut into the surface. Water in rivers flows from a higher point to a lower one and it is affected by gravity. They can cause flooding, which leads to significant economic damage for the surrounding population and, in some cases, even endangers lives.

Depending on the flow of water, we distinguish between rivers and streams.

A stream has a lower flow than a river. It has a small, shallow and narrow riverbed. The water in the stream carries away the material in it and along the riverbed. They usually flow into larger streams or rivers, and then indirectly into the sea. During water shortages or droughts, it dries up before the river. Streams flow over all types of surfaces. We know forest, meadow, roadside... streams.



Figure 18: Kroparica stream.

The river (Sava) has a greater flow than a stream. It has a deeper, larger and wider riverbed. It usually flows into a lake, a larger river or the sea. It causes more erosion than streams and, in the event of flooding, the damage is greater than in the case of streams.

(Source 27, source 28, source 29, source 30, source 31, source 32, source 33, source 34, source 35)



Figure 19: River.

### HYDROLOGY OF POLLUTION

Pollution hydrology is a branch of hydrology which, among other sciences, is part of geophysics. It deals with water quality, storage, disposal and spreading of pollution in water. In this research assignment, the focus is on the quality of bathing waters.

Quality is the term for the physical, chemical and biological characteristics of water, usually assessed according to the intended use. Bathing water must be free of micro-organisms, as these can cause many diseases. Water protection is needed to prevent micro-organisms from multiplying excessively in bathing waters. To this end, the European Commission adopted *the* *Water Directive* in 2000, providing the EU Member States with the legal and technical basis for an integrated approach to water protection and management. The main goal of *the Water Directive* is to achieve a good chemical and ecological state of waters.



Figure 20: Polluted water.

Water is polluted by chemicals, particles, industrial, agricultural and residential waste, noise and the spread of invasive organisms. Air pollution is another factor that carries pesticides or dirt. Once pesticides are incorporated into aquatic ecosystems, they are rapidly absorbed into the food chain. When they enter the food chain, they can cause mutations as well as diseases that can be harmful to the entire food chain. It is important that the food chain in the water body remains stable, as this keeps the entire ecosystem in the water body in balance. If this collapses, one or more animal or plant species will dominate and spread excessively.



Figure 21: A river full of waste.

One form of water pollution relates to contamination from excessive nutrient inputs. This is often the main reason for eutrophication of surface waters, where excess nutrients (usually nitrogen or phosphorus) stimulate algae growth. Eutrophication is the process of increasing the amount of biomass in water because of increased concentrations of inorganic nutrients (nitrates and phosphates) in an ecosystem. This phenomenon is most often observed in stagnant or slow-moving bodies of water, where these substances are most likely to become stagnant. A greater amount of nutrients enables the rapid reproduction of algae that overgrow the surface of the water body. This phenomenon is called water bloom. This mass of algae also decays in large numbers and the bacterial decomposition of dead organic material is oxygen intensive. This causes the oxygen concentration in the watercourse to decrease and become insufficient for other organisms (insects, fish, etc.) to survive. Their death further accelerates eutrophication. Eutrophication is most often caused by sewage wastewater and fertilized farmland entering the natural environment. It is particularly noticeable in densely populated areas and areas with intensive agriculture. Eutrophication is considered pollution as it is usually an artificial change in the natural cycling of substances.

(Source 36, Source 37, Source 38, Source 39, Source 40)

## GLOBE PROTOCOLS

### INTRODUCTION TO GLOBE PROTOCOLS



Water is the main source of life and is important in many chemical reactions. The Globe protocols are designed to provide accurate data when all instructions are followed. As in other spheres, it is also necessary to follow different protocols in the hydrosphere since different characteristics of water influence each other. Within each protocol, it is written when additional measurements need to be performed, in order to increase the accuracy of the measurements. It is recommended that hydrosphere data be collected once a week. The hydrosphere focuses on water and bodies of water. Hydrological protocols include measurements of water temperature, water clarity, pH, dissolved oxygen, electrical conductivity, salinity, alkalinity, nitrates, nitrites, phosphates and ammonium ions.

Figure 22: GLOBE logo.

### CHOICE OF SITES

All measurements must be taken in the same place. This site can be any surface water area that can be safely visited and regularly monitored. Information about your study site can be provided in 3 ways: written comments (description of the measurement site, changes that may affect the results), with photos (4 photos-against each main direction of the sky, while standing where the water sample is taken) and with the help of maps.



Figure 23: Selecting a site.

First, we collect position data using a GPS receiver. Next, the name of the body of water, the salinity or sweetness of the water and whether the water is flowing or standing (if flowing, write the width, if standing, the approximate surface area and depth). This is followed by a record of the sampling site (whether the bottom is visible, type of substrate). It is necessary to write down all observations. This could be, for example, any discharges into a body of water, whether it is artificial or natural, plant and animal species observed, the amount of vegetation, the value of water to humans.

### WATER TEMPERATURE MEASUREMENT PROTOCOL



The measurement of water temperature determines how hot or cold the water is. Water has a higher specific heat (heat capacity) than air, so it heats and cools more slowly. Water temperature can be referred to as the master variable, as it affects almost all the properties of water and the chemical reactions that occur in it. It determines which organisms can live in a particular body of water. Cold lakes with few plant life in winter, bloom in spring and summer, when the water temperature rises and the nutrient-rich lower waters mix with the upper waters.

Figure 24: Thermometer.

Many fish and other aquatic animals spawn at this time of year when temperatures are higher and food is plentiful. Shallow lakes are an exception, as the lower rich waters mix with the upper waters throughout the year. Water temperature is important since too high temperatures can be fatal for sensitive species (trout, salmon). Dissolved oxygen is less abundant in waters with higher temperatures. Water helps the air temperature by evaporation and condensation.

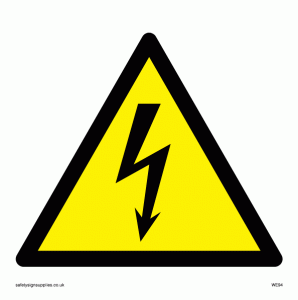
The temperature measurement can be performed with an alcohol thermometer or with a temperature probe.

### WATER TRANSPARENCY PROTOCOL

Water transparency is one of the measurements used to describe the condition of a body of water. The depth of light penetration into the water is measured. It depends on the amount of suspended particles in the water. The particles limit the penetration of light through the water and contribute to the colour and transparency of the water. Particles will reflect, absorb, or scatter light, determining the depth at which light can no longer penetrate. These particles can be organic (phytoplankton, algae), inorganic (sediment) or other dissolved impurities (organic or inorganic carbonates). Dark or black materials absorb most wavelengths of light, while white materials reflect most wavelengths of light. Rivers with high sediment content tend to be the same colour as the sediment.

For measurement, we may use a Secchi disk (for deep and still water) and a clear tube (shallow and flowing water). The Secchi disk measures the water tower. Light penetration may vary depending on the depth of water in this tower. All the light reflected from the Secchi disk passes through the water from the surface. A transparent tube measures the transparency of a water sample taken just below the surface. Light can enter the transparent tube both from the side and from above. Water sampling is different for both methods, so the results are not directly comparable.

### ELECTRICAL CONDUCTIVITY PROTOCOL



Electrical conductivity measures the ability of water to conduct electricity. It measures how much electricity is conducted through one centimetre of water. The unit of measurement is μS/cm. It provides a general measurement of the quality of running water. Electrical conductivity is a good indicator of the total level of impurities in fresh water. The content of mineral and salt impurities in water represents the total value of dissolved substances (abbreviated TDS - total dissolved solids; it is measured as parts per million (ppm)).

Figure 25: Electricity symbol.

Electrical conductivity is affected by temperature. The higher the temperature, the higher the electrical conductivity of the water. Pure water is a poor conductor of electricity. The more ions in the water, the better the water will conduct electricity.

### WATER pH MEASUREMENT PROTOCOL

The concentration of hydrogen ion activity (H+) determines the pH of a solution. pH is given in logarithmic units from 0 to 14. Where 0 is the most acidic and 14 the most alkaline. A value of around 7 means that the pH is neutral. Most lakes have pH values between 6.5 and 8.5. Alkaline waters occur in areas where the soil is rich in minerals. Acids and alkalis enter water as by-products of human activities. The pH of water affects most of the chemical and biological processes that occur in water.

It affects the solubility and bioavailability of nutrients. It determines the degree of solubility of potentially toxic materials (e.g. heavy metals).

A pH of 0-3 is lethal to all living things in water. The best environment for all organisms is 6.5-8.2. A pH of 11-14 is lethal to all aquatic life.

A pH meter or pH strips can be used for measurement. The accuracy depends on the electrical conductivity, which must be at least 200 µS/cm.

Figure 26: pH strips.

### DISSOLVED OXYGEN PROTOCOL

Oxygen molecules dissolved in water are necessary for the respiration of aquatic animals such as fish and zooplankton. The amount of dissolved oxygen depends on many factors, i.e. water temperature, air pressure and salinity. Colder water has more dissolved oxygen than warmer water. Water at higher altitudes has less dissolved oxygen due to the lower air pressure. As salinity increases, the solubility of oxygen decreases. Dissolved oxygen can be added to water by plants during photosynthesis, and can diffuse into water from the atmosphere.



It can be measured with the help of an oxygen probe. However, it is necessary to know that after taking a sample, the amount of dissolved oxygen changes quickly, so it is best to carry out testing in the field.

Figure 27: Oxygen molecule.

### WATER ALKALINITY (BASICITY) PROTOCOL

Alkalinity and pH are related yet distinct properties of water. Alkalinity is a measurement of the water's resistance to pH reduction when acids are added to water and enter the water through rain, snow, dissolved rocks or soil. Alkalinity is expressed as the amount of calcium carbonate in the water. A large influx of acids from heavy rainfall or rapid snowmelt causes the pH to drop to a level that is harmful to aquatic organisms. When water is high in alkalinity, it is known as being well buffered (it is resistant to pH reduction when acidic water enters the system). Lakes and streams in areas with a rich limestone substrate are more alkaline than those in landscapes with a non-carbonate substrate. The unit for alkalinity is mg/L. Waters with higher alkalinity are more resistant to changes in pH. Alkalinity of water decreases with a large return of rain or snow to the water.

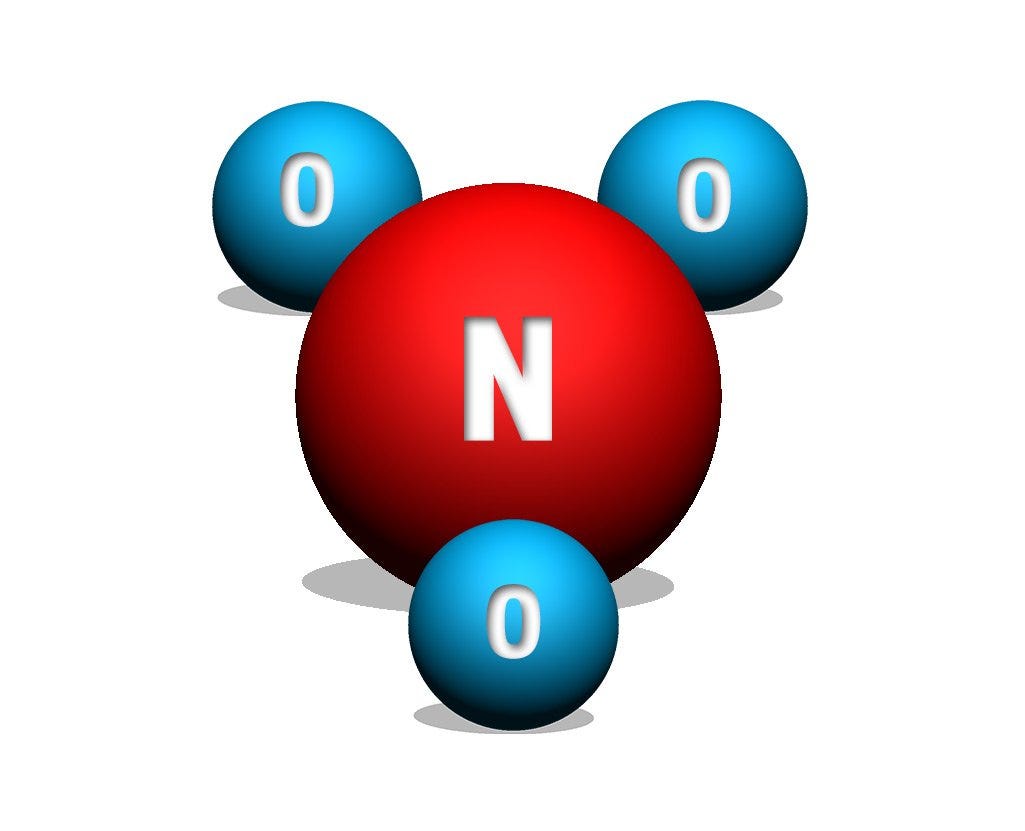
### WATER SALINITY PROTOCOL

Salinity is a measurement of the total grams of salt dissolved in 1 kg of brine. It is expressed in percentages or parts per mill. Sodium and chloride ions are the main contributors to salinity. Freshwater organisms are saltier than the water they live in. In lakes and rivers, salinity is less than 35 ppt (parts per thousand) due to a constant inflow of freshwater from the soil or rain; it can exceed 35 ppt due to high evaporation rates. There are salt lakes such as the Caspian Sea (Central Asia), the Great Salt Lake (North America) and several lakes in East Africa.

Figure 28: Salt.

However, they are salty due to the water flowing into them and then evaporating, leaving the salt in the inland sea or lake. Freshwater lakes, unlike saltwater lakes, have outlets, so salts move through the lakes instead of accumulating in them. Data is collected with a hydrometer or salinity titration. The hydrometer method is quick and easy, and does not generate additional chemical by-products that need to be disposed of as chemical waste. The salinity titration method takes a long time and produces a chromium by-product that must be disposed of as chemical waste.

### NITRATE DETERMINATION PROTOCOL



In bodies of water, nitrogen exists in many forms, such as dissolved molecular nitrogen, organic compounds, ammonium, nitrite, and nitrate. Nitrate is an important inorganic form of nitrogen, as it is an essential nutrient for the growth and reproduction of many algae and other aquatic plants. Unicellular algae respond quickly to increased nitrate concentrations in the water, multiplying excessively and triggering eutrophication processes ('water enrichment'), which in the long term leads to a lack of oxygen for other aquatic organisms. The resulting excessive growth can cause taste and odor problems in lakes used for drinking water.

Figure 29: Nitrate molecule.

Water fouling can lead to reduced light levels in water bodies. When plants and algae die, bacteria multiply and use up the dissolved oxygen in the water. The amount of dissolved oxygen is therefore reduced, endangering other aquatic animals. Nitrates are common pollutants carried by water runoff from over-fertilised agricultural fields. Nitrite is found in waters with low levels of dissolved oxygen. Nitrogen limits the amount of plants in water as plants use up all the available nitrogen in the water and can no longer grow and reproduce. Nitrate form of nitrogen enters water from the atmosphere through rain, snow, fog, groundwater and surface and groundwater flowing through the soil. Human activities impact nitrate levels in water bodies too.

### FRESHWATER MACROINVERTEBRATES PROTOCOL

Macroinvertebrates include various insects and their larva, crustaceans, molluscs, worms and other small non-vertebrates. They live in mud, sand or on submerged plants and underwater objects. They are an essential link in the food chain and are a source of food for other larger animals. Some macroinvertebrates (freshwater mussels) filter water, others live as saprophytes, and the rest as predators or scavengers. Many are sensitive to changes in pH, dissolved oxygen, temperature, salinity and transparency. Macroinvertebrate samples allow us to assess biodiversity, study the ecology of the water body and the relationships between the chemical properties of the water and the organisms in the selected area. Sampling takes place twice a year, in spring and autumn.

(Source 41, source 42, source 43)

# EXPERIMENTAL/RESEARCH PART

## RESEARCH QUESTION AND HYPOTHESES

People love to bathe in nature. It does not matter whether it is a lake, a waterfall, a stream or a river. As we have observed a lot of bathers in the bodies of water near our homes, a research question arose about the quality of bathing waters in Slovenia.

We have formulated some hypotheses that will be accepted or refuted based on our research work.

Hypothesis 1: The Sava is more suitable for bathing than lakes due to its higher water flow.

Hypothesis 2: Water temperature will be higher in standing bodies of water (lakes) compared to the Sava.

Hypothesis 3: Nitrate concentration influences nitrite concentration. Where higher concentrations of nitrate are found, higher concentrations of nitrite will occur as well.

Hypothesis 4: Nitrate concentrations in water are higher in the river Sava than in lakes. This could be due to the proximity of cultivated areas, extending to the river in some places.

Hypothesis 5: Ammonium ion levels will be increased in standing bodies of water due to poorer treatment systems, as it enters the water from animal excrement.

Hypothesis 6: Phosphate concentration is increased in the Sava due to the proximity of settlements and industrial plants.

Hypothesis 7: Ph will be higher in lakes than in the Sava.

Hypothesis 8: The hardness and pH of water are proportionally related to each other, as the pH of water affects its hardness.

## METHODS OF WORK

We analysed water from four locations; Lake Kočevje, Lake Bloke, Lake Podpeč and the river Sava. Some experiments were carried out on the spot, next to the water body, and some in the laboratory. We measured the temperature and pH of the water in the field. In the school laboratory, we tested the hardness of water, the content of nitrates (NO3-), nitrides (NO2-), ammonium ions (NH4+), sulphates (SO4 2-) and phosphates (PO4 3-).

Figure 30: The chemicals used for the chemistry experiments.

At the Faculty of Chemistry and Chemical Technology, the content of chloride ions (Cl-), nitrates (NO3-), nitrides (NO2-), sulphates (SO4 2-) and phosphates (PO4 3-) was measured by ion chromatography.

## DESCRIPTION OF THE LABORATORY

Temperature and pH measurements were carried out at the site of the studied water body, i.e. by the lakes Bloke, Kočevje, Podpeč and the river Sava.

Figure 31: Measurement area at Lake Bloke.



Figure 32: Measurement area on the river Sava.



Figure 33: Measurement area at Lake Podpeć.



Figure 34: Lake Kočevje.

Chemical experiments were carried out in the laboratory at the Ledina Gymnasium under the guidance of prof. Nika Cebin.

Ion chromatography of samples of the described water bodies was carried out at the Faculty of Chemistry and Chemical Technology in Ljubljana under the guidance of Gregor Marolt.



Figure 35: Chemistry laboratory of the Ledina Gymnasium.



Figure 36 : Faculty of Chemistry and Chemical Technology Ljubljana.

# RESULTS

## NITRITE

Nitrite is an anion consisting of one nitrogen atom and two negatively charged oxygen atoms. The formula for nitrite is NO₂⁻. It can be thought of as a salt or ester of nitric (III) or nitric acid. It presents a serious health risk to humans, especially children, as it is poisonous and in some cases can result in death. Nitrate (III) ions are used as preservatives in dried meat products, ham, smoked meats, rye and fish. They are found in water mainly due to the use of artificial and natural fertilisers, in municipal sewage, and in industrial applications. They are well soluble in water. Nitrite ions are toxic to all living beings. The nitrate (III) ions react with amines in the intestinal tract to form carcinogenic nitrosamines.

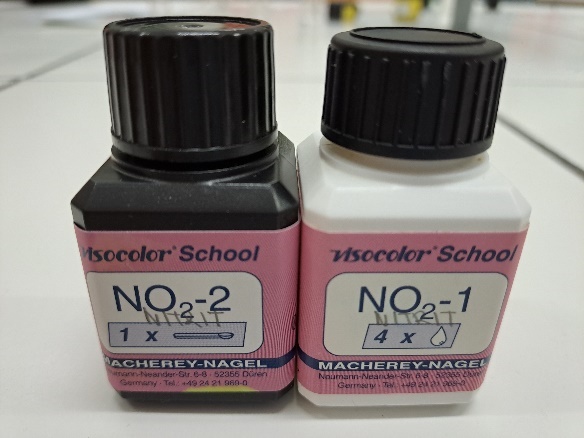
According to Slovenian legislation, the limit value of nitrite in water is 0.50 mg/L or 0.10 mg/L in drinking water. The measurement range is from 0.02-0.5 mg/L NO2-.

Figure 37: Chemicals used to measure nitrite.

### THE EXPERIMENT PROCEDURE

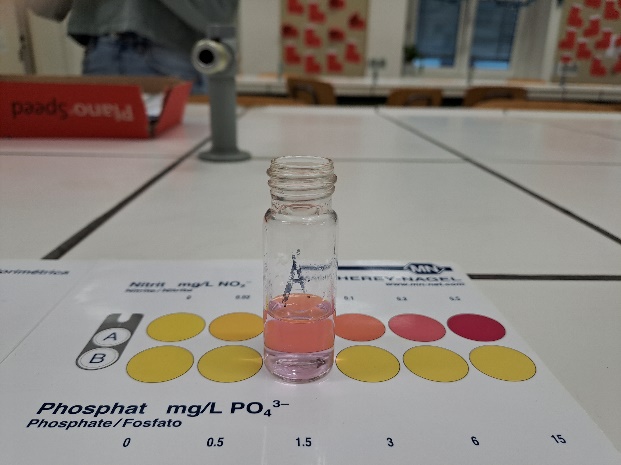
1. We measured 5 ml of sample into 2 cuvettes and placed them in a comparator, one labelled A and the other B.   
2. We added 4 drops of NO2 --1 reagent to cuvette B, sealed it with a cap and mixed it well.   
3. Then 1 measuring spoon of NO2 --2 reagent was added to cuvette B.   
4. Cuvette B was closed and stirred until the reagent was completely dissolved in the powder.   
5. We waited 10 minutes before opening the caps on both cuvettes and reading the result using the colour scale.

Figure 38: Nitrite measurement.

### LAKE BLOKE

|  |  |
| --- | --- |
| Date of sampling | γ (NO 2- ) [mg/L] |
| 24/09/2022 | 0 |
| 01.10.2022 | 0 |
| 08.10.2022 | 0 |
| 15/10/2022 | 0.02 |
| 22/10/2022 | 0 |
| 29/10/2022 | 0.02 |
| 05.11.2022 | 0.02 |
| 11/12/2022 | 0 |
| 11/19/2022 | 0 |
| 26/11/2022 | 0.02 |
| 03.12.2022 | 0.50 |
| 10/12/2022 | 0.01 |
| 17/12/2022 | 0.01 |

Table 1: Mass concentration (γ) of nitrites in Lake Bloke for the period between 24.9.2022 and 17.12.2022.

During the measurements, the mass concentration of nitrites in the water ranged from 0 to 0.02 mg/L. The only exception was on 3.12.2022, when a concentration of 0.50 mg/L nitrite ions was measured in the water. Concentrations of nitrate (III) ions or nitrite ions comply with Slovenian legislation, although occasionally they approach the maximum nitrite ion concentration still allowed by Slovenian legislation.

### LAKE PODPEČ

|  |  |
| --- | --- |
| Date of sampling | γ (NO 2- ) [mg/L] |

|  |  |
| --- | --- |
| 24/09/2022 | 0 |
| 01.10.2022 | 0 |
| 08.10.2022 | 0 |
| 15/10/2022 | 0 |
| 22/10/2022 | 0.50 |
| 29/10/2022 | 0.50 |
| 05.11.2022 | 0.02 |
| 11/12/2022 | 0.02 |
| 11/19/2022 | 0.01 |
| 26/11/2022 | 0 |
| 03.12.2022 | 0.05 |
| 10/12/2022 | 0 |
| 17/12/2022 | 0 |

Table 2: Mass concentration (γ) of nitrites in Lake Podpeč for the period between 24.9. and 17.12. 2022.

During the measurements, the mass concentration of nitrites in the water ranged from 0 to 0.02 mg/L. On 22.10.2022 and 29.10.2022, we set the maximum nitrite concentration still allowed (0.50 mg/L). Concentrations of nitrite ions meet the requirements of Slovenian legislation, although occasionally approaching the maximum level still allowed.

### LAKE KOČEVJE

|  |  |
| --- | --- |
| Date of sampling | γ (NO 2- ) [mg/L] |

|  |  |
| --- | --- |
| 05.10.2022 | 0 |
| 12/10/2022 | 0 |
| 19/10/2022 | 0.01 |
| 26/10/2022 | 0.02 |
| 05.11.2022 | 0.02 |
| 11/12/2022 | 0.02 |

Table 3: Mass concentration (γ) of nitrites in Lake Kočevje for the period between 5.10.2022 and 12.11 2022.

During the measurements, the amount of nitrite ions varied from 0 to 0.02 mg/L. The mass concentrations of nitrite ions were quite low, with the highest and most frequently determined mass concentration of nitrite ions being 0.02 mg/L. The amounts of nitrite ions are low and therefore meet the criteria of Slovenian legislation.

### SAVA

|  |  |
| --- | --- |
| Date of sampling | γ (NO 2- ) [mg/L] |

|  |  |
| --- | --- |
| 24/09/2022 | 0.01 |
| 01.10.2022 | 0.01 |
| 08.10.2022 | 0 |
| 15/10/2022 | 0.01 |
| 22/10/2022 | 0 |
| 29/10/2022 | 0.01 |
| 05.11.2022 | 0.01 |
| 11/12/2022 | 0.01 |
| 11/19/2022 | 0.01 |
| 26/11/2022 | 0.02 |
| 03.12.2022 | 0.02 |
| 10/12/2022 | 0.03 |

Table 4 : Mass concentration (γ) of nitrites in the river Sava for the period between 24.9. and 10/12/2022.

At the time of the measurements, the mass concentrations of nitrite ions in the Sava were mostly 0 or 0.01 mg/L. Higher levels were observed only on 26.11.2022 and 3.12.2022, when the concentration of nitrite ions was 0.02 mg/L. Maximum value was on 10.12.2022, when it reached 0.03 mg/L.All values comply with the criteria of the Slovenian legislation.

## NITRATE

The nitrate ion (NO3-) is the conjugate base of nitric acid (HNO3), consisting of a central nitrogen atom and three oxygen atoms in a trigonal planar arrangement.

The increase in nitrates is caused by runoff from areas exposed to high levels of nitrogen fertilizer (e.g., fields). Increased concentrations often lead to algae blooms, leading to oxygen deficiency in the aquatic ecosystem. Among other things, an increased concentration can hinder growth, weaken the immune system and cause stress to certain types of aquatic organisms.

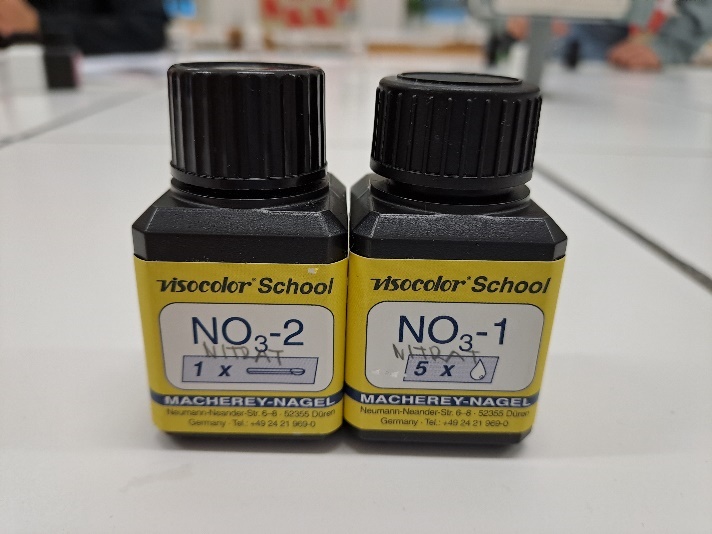
According to Slovenian legislation, the limit value is 50 mg/L. The measuring range is between 1 – 90 mg/L NO 3-.  


Figure 39: Chemicals used to measure nitrate.

### THE EXPERIMENT PROCEDURE

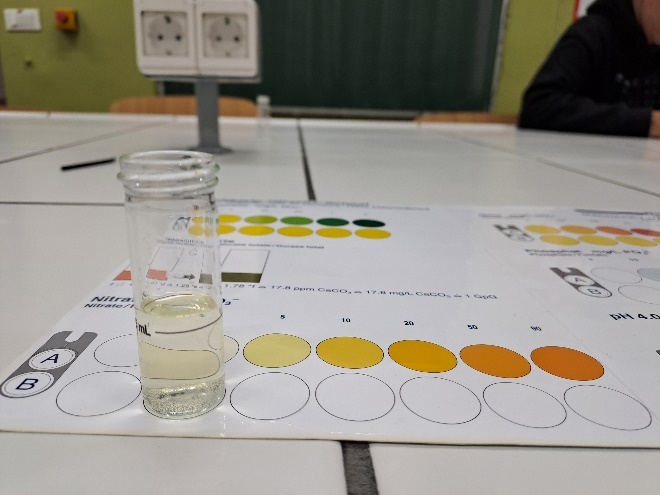
1. We measured 5 ml of the sample in 2 cuvettes and placed them in the comparator, one was marked with A, the other with B.   
2. In cuvette B, we added 5 drops of the reagent NO3 --1 and closed it with a cap.   
3. Cuvette B was well mixed.   
4. In cuvette B, 1 measuring spoon of NO3--2 reagent was added, sealed and stirred continuously for 1 minute.   
5. We waited 10 minutes before opening the caps on both cuvettes and reading the result using the colour scale.

Figure 40: Nitrate measurement.

### LAKE BLOKE

|  |  |
| --- | --- |
| Date of sampling | γ (NO 3 - ) [mg/L] |
| 24/09/2022 | 1.00 |
| 01.10.2022 | 1.00 |
| 08.10.2022 | 1.00 |
| 15.10.2022 | 1.00 |
| 22.10.2022 | 1.00 |
| 29.10.2022 | 1.00 |
| 05.11.2022 | 1.00 |
| 12.11.2022 | 1.00 |
| 19.11.2022 | 1.00 |
| 26.11.2022 | 1.00 |
| 03.12.2022 | 2.50 |
| 10.12.2022 | 1.00 |
| 17.12.2022 | 2.00 |

Table 5: Mass concentration (γ) of nitrates in Lake Bloke for the period between 24.9. and 17.12.2022.

During the measurements, with the exception of 3.12.2022 (when the value was 2.50 mg/L) and 17.12.2022 (when the value was 2.00 mg/L), the mass concentration of nitrate ions in Lake Bloke was 1.00 mg/L. These values correspond to the limit of Slovenian legislation.

### LAKE PODPEČ

|  |  |
| --- | --- |
| Date of sampling | γ (NO 3 - ) [mg/L] |

|  |  |
| --- | --- |
| 24/09/2022 | 1:50 a.m |
| 01.10.2022 | 1:50 a.m |
| 08.10.2022 | 1:00 a.m |
| 15/10/2022 | 1:50 a.m |
| 22/10/2022 | 5:00 a.m |
| 29/10/2022 | 7:50 a.m |
| 05.11.2022 | 1:50 a.m |
| 11/12/2022 | 1:00 a.m |
| 11/19/2022 | 1:00 a.m |
| 26/11/2022 | 1:00 a.m |
| 03.12.2022 | 5:00 a.m |
| 10/12/2022 | 1:00 a.m |
| 17/12/2022 | 1:00 a.m |

Table 6: Mass concentration (γ) of nitrates in Lake Podpeč for the period between 24.9. and 17.12.2022.

The mass concentration of nitrate ions in Lake Podpeč was mostly between 1.00 and 1.50 mg/L. The exceptions were mass concentrations on 22.10.2022, 3.12.2022 and 29.10.2022. All these concentrations correspond to the criteria of Slovenian legislation.

### LAKE KOČEVJE

|  |  |
| --- | --- |
| Date of sampling | γ (NO 3 - ) [mg/L] |

|  |  |
| --- | --- |
| 05.10.2022 | 0 |
| 12/10/2022 | 0.01 |
| 19/10/2022 | 0 |
| 26/10/2022 | 0 |
| 05.11.2022 | 0.50 |
| 11/12/2022 | 0.50 |

Table 7: Mass concentration (γ) of nitrates in Lake Kočevje for the period between 5.10. and 12.11.2022.

Mass concentrations of nitrate ions in Lake Kočevje varied between 0.00 mg/L and 0.50 mg/L. 5. and are in accordance with the criteria of Slovenian legislation.

### SAVA

|  |  |
| --- | --- |
| Date of sampling | γ (NO 3 - ) [mg/L] |

|  |  |
| --- | --- |
| 24/09/2022 | 1:00 a.m |
| 01.10.2022 | 0.50 |
| 08.10.2022 | 1:00 a.m |
| 15/10/2022 | 1:00 a.m |
| 22/10/2022 | 0.50 |
| 29/10/2022 | 1:50 a.m |
| 05.11.2022 | 1:50 a.m |
| 11/12/2022 | 1:50 a.m |
| 11/19/2022 | 1:00 a.m |
| 26/11/2022 | 1:00 a.m |
| 03.12.2022 | 2.50 |
| 10/12/2022 | 2.50 |

Table 8: Mass concentration (γ) of nitrates in the river Sava for the period between 24.9. and 10.12.2022.

Mass concentrations fluctuated from September to December, as they were between concentrations of 0.50 - 2.50 mg/L. All specific concentrations correspond to the criteria of Slovenian legislation.

## PHOSPHATE

Phosphates are salts of phosphoric acid (H3PO4). The phosphate ion PO4 3- consists of a central phosphorus atom surrounded by four oxygen atoms in a tetrahedral form. Phosphates are essential in biochemistry. They are included in the essential molecules for the complete flora and fauna (e.g., DNA-deoxyribonucleic acid, ATP-adenosine triphosphate).

Phosphate contamination of water is mostly caused by household wastewater, containing large amounts of washing powders and detergents. Leaching of artificially fertilized land (high phosphate content) into groundwater is another common occurrence. Along with nitrate, phosphate is the main cause of algal blooms and fish diseases.

The measurement range is from 0.5 to 15 mg/L.

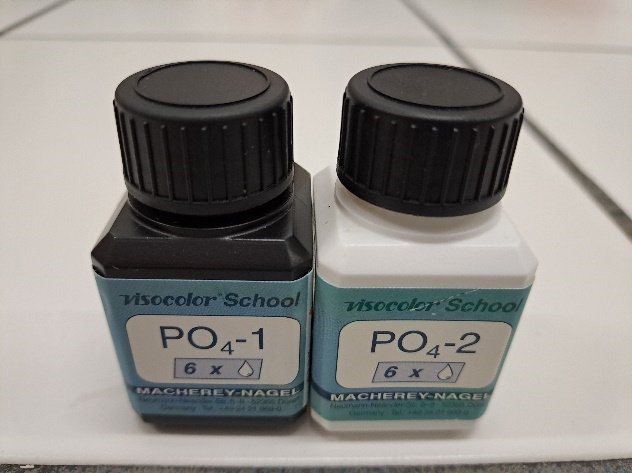


Figure 41: Chemicals used to measure phosphate.

### THE EXPERIMENT PROCEDURE

1. We measured 5 ml of sample into 2 cuvettes and placed them in a comparator, one marked A, the other B.   
2. We added 6 drops of reagent PO4 -1 to cuvette B, closed it with a cap and mixed well.   
3. We added 1 measuring spoon of reagent PO43- -2 to cuvette B.   
4. We closed cuvette B and stirred it so that the reagent in the powder was completely dissolved.   
5. We waited 10 minutes before opening the caps on both cuvettes and reading the result using the colour scale.

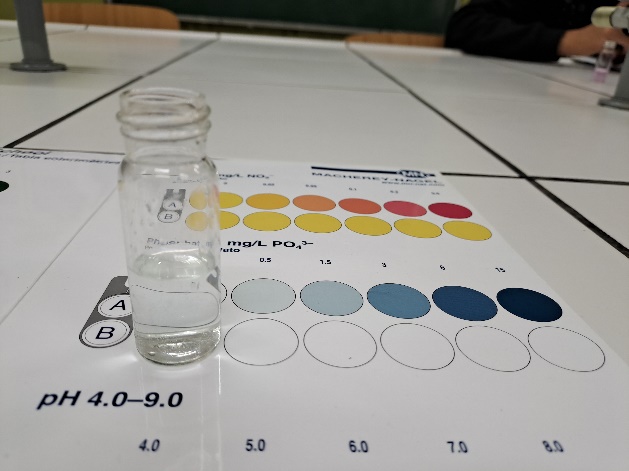


Figure 42: Phosphate measurement.

### LAKE BLOKE

|  |  |
| --- | --- |
| Date of sampling | γ (PO 4 3- ) [mg/L] |
| 24/09/2022 | 0.25 |
| 01.10.2022 | 0 |
| 08.10.2022 | 0.50 |
| 15.10.2022 | 0 |
| 22.10.2022 | 0 |
| 29.10.2022 | 0.50 |
| 05.11.2022 | 0.50 |
| 12.11.2022 | 1.00 |
| 19.11.2022 | 0 |
| 26.11.2022 | 0 |
| 03.12.2022 | 0.25 |
| 10.12.2022 | 0 |
| 17.12.2022 | 0.25 |

Table 9: Mass concentration (γ) of phosphates in Lake Bloke for the period between 24.9. and 17.12.2022.

The mass concentration of phosphate ions in the samples of Lake Bloke varied from 0 to 0.50 mg/L. The value was higher only on 12.11.2022 when it reached 1 mg/L.

### LAKE PODPEČ

|  |  |
| --- | --- |
| Date of sampling | γ (PO 4 3- ) [mg/L] |

|  |  |
| --- | --- |
| 24/09/2022 | 0.50 |
| 01.10.2022 | 0.50 |
| 08.10.2022 | 0 |
| 15/10/2022 | 0 |
| 22/10/2022 | 0 |
| 29/10/2022 | 0 |
| 05.11.2022 | 0 |
| 11/12/2022 | 0 |
| 11/19/2022 | 0 |
| 26/11/2022 | 0.25 |
| 03.12.2022 | 0.50 |
| 10/12/2022 | 0 |
| 17/12/2022 | 0.25 |

Table 10: Mass concentration (γ) of phosphates in Lake Podpeč for the period between 24.9. and 17.12.2022.

During the measurements, the amount of phosphate ions in the water sample of Lake Podpeč ranged from 0 to 0.50 mg/L. No phosphate ions were determined between 8.10.2022 and 19.11.2022 (Table 10).

### LAKE KOČEVJE

|  |  |
| --- | --- |
| Date of sampling | γ (PO 4 3- ) [mg/L] |

|  |  |
| --- | --- |
| 05.10.2022 | 0 |
| 12/10/2022 | 0 |
| 19/10/2022 | 0 |
| 26/10/2022 | 0 |
| 05.11.2022 | 0 |
| 11/12/2022 | 0 |

Table 11: Mass concentration (γ) of phosphates in Lake Kočevje for the period between 5.10. and 12.11.2022.

We did not determine the presence of phosphate ions in Lake Kočevje (Table 11).

### SAVA

|  |  |
| --- | --- |
| Date of sampling | c (PO 4 3- ) [mg/L] |

|  |  |
| --- | --- |
| 24.09.2022 | 0.50 |
| 01.10.2022 | 0.50 |
| 08.10.2022 | 1 |
| 15.10.2022 | 0.50 |
| 22.10.2022 | 0.50 |
| 29.10.2022 | 0.50 |
| 05.11.2022 | 0 |
| 12.11.2022 | 0 |
| 19.11.2022 | 0 |
| 26.11.2022 | 0.10 |
| 03.12.2022 | 0.10 |
| 10.12.2022 | 0 |

Table 12: Mass concentration (γ) of phosphates in the river Sava for the period between 24.9. and 10.12.2022.

Mass concentrations of phosphate ions in water samples from the Sava varied between 0 and 0.50 mg/L. However, the only exception was on 8.10.2022, when the maximum concentration of phosphate ions measured in the sample was 1 mg/L. Most frequently, a PO43- ion concentration of 0.50 mg/L was determined (Table 12).

## AMMONIUM ION

Ammonium ion NH4+ is a positively charged cation formed by protonation of ammonia:

Picture 23NH3(aq) + H2O(l) NH4+(aq) + OH-(aq)

It is toxic to organisms, therefore they have developed different ways of excreting it, e.g. fish and other aquatic organisms excrete it directly into the water, mammals and amphibians excrete it in the form of urea, and birds and reptiles excrete it in the form of uric acid. It is formed by a reaction between ammonia, representing a weak base, and an acid, acting as a proton donor. It is a strong conjugated acid and can react with alkali to cause a deprotonation, resulting in the formation of ammonia. When ammonia dissolves in water, a significant part of the ammonia reacts with the oxonium ion to form ammonium ions. It is found in manure and fertilisers, is highly toxic to aquatic life, however, it does not pose a significant risk to human health. The presence of ammonium in water tells us that the water has been exposed to decaying organic matter from agricultural, municipal or industrial waste. In concentrations expected in drinking water, it does not pose a direct threat to human health.

According to Slovenian legislation, the limit value is 0.50 mg/L. The measurement range is from 0.2 to 3 mg/L.

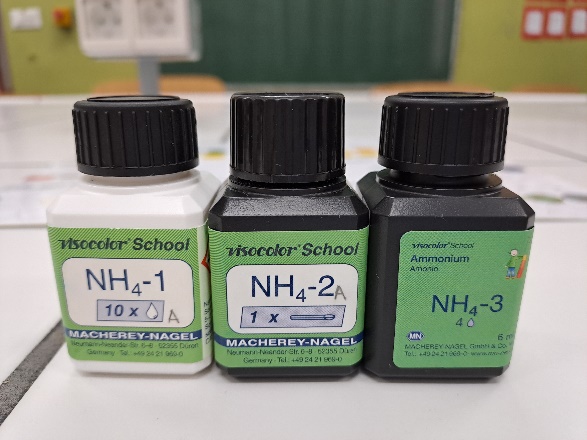


Figure 43: Chemicals used to measure ammonium ion.

### THE EXPERIMENT PROCEDURE

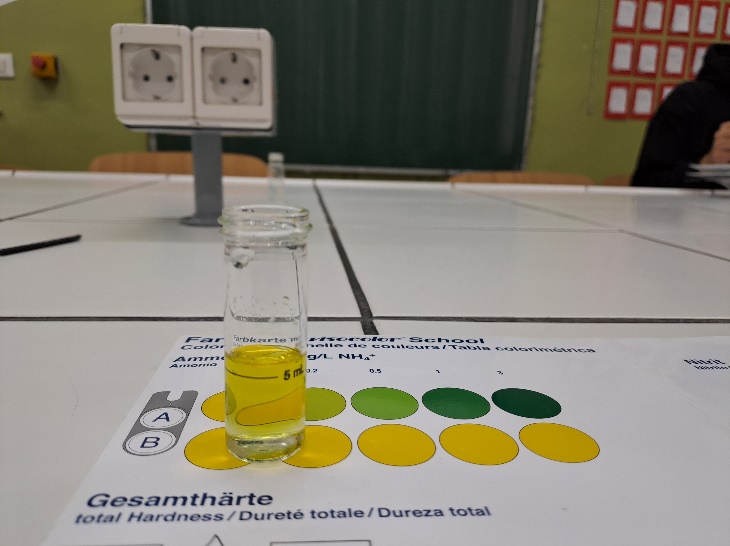
1. We measured 5 ml of sample into 2 cuvettes and placed them in a comparator, one marked A, the other B.   
2. We added 10 drops of NH4+-1 reagent to cuvette B and sealed it with a cap and mixed it well.   
3. To cuvette B, we added 1 measuring spoon of the NH4+-2 reagent, sealed it and stirred until the reagent was completely dissolved in the powder. We waited 5 minutes.  
4. We opened cuvette B and added 4 drops of NH4+-3 and closed and mixed well.   
5. We waited 7 minutes and opened the caps on both cuvettes and read the results using the colour scale.

Figure 44: Ammonium ion measurement.

### LAKE BLOKE

|  |  |
| --- | --- |
| Date of sampling | γ (NH 4 + )[mg/L] |
| 24.09.2022 | 0 |
| 01.10.2022 | 0 |
| 08.10.2022 | 0 |
| 15.10.2022 | 0 |
| 22.10.2022 | 0 |
| 29.10.2022 | 0.10 |
| 05.11.2022 | 0.10 |
| 12.11.2022 | 0.10 |
| 19.11.2022 | 0.10 |
| 26.11.2022 | 0.10 |
| 03.12.2022 | 0.10 |
| 10.12.2022 | 0.10 |
| 17/12/2022 | 0.10 |

Table 13: Mass concentration (γ) of ammonium ion in Lake Bloke for the period between 24.9. and 17.12.2022.

In the water samples from Bloke, the mass concentration of ammonium ions was between 0 and 0.10 mol/L (Table 13).

### LAKE PODPEČ

|  |  |
| --- | --- |
| Date of sampling | γ (NH 4 + )[mg/L] |

|  |  |
| --- | --- |
| 24/09/2022 | 0.10 |
| 01.10.2022 | 0.10 |
| 08.10.2022 | 0.10 |
| 15/10/2022 | 0.10 |
| 22/10/2022 | 0.10 |
| 29/10/2022 | 0.10 |
| 05.11.2022 | 0.10 |
| 11/12/2022 | 0.10 |
| 11/19/2022 | 0.10 |
| 26/11/2022 | 0.10 |
| 03.12.2022 | 0.10 |
| 10/12/2022 | 0.10 |
| 17/12/2022 | 0.10 |

Table 14: Mass concentration (γ) of ammonium ion in Lake Podpeč for the period between 24.9. and 17.12.2022.

Mass concentrations of ammonium ions in all water samples from Lake Podpeč were 0.10 mg/L (Table 14).

### LAKE KOČEVJE

|  |  |
| --- | --- |
| Date of sampling | γ (NH 4 + )[mg/L] |

|  |  |
| --- | --- |
| 05.10.2022 | 0.10 |
| 12/10/2022 | 0.10 |
| 19/10/2022 | 0.10 |
| 26/10/2022 | 0.10 |
| 05.11.2022 | 0.10 |
| 11/12/2022 | 0.10 |

Table 15: Mass concentration (γ) of ammonium ion in Lake Kočevje for the period between 5.10. and 12.11.2022.

Mass concentrations of ammonium ions in all water samples from Lake Kočevje were 0.10 mg/L (Table 15).

### SAVA

|  |  |
| --- | --- |
| Date of sampling | γ (NH 4 + )[mg/L] |

|  |  |
| --- | --- |
| 24.09.2022 | 0 |
| 01.10.2022 | 0 |
| 08.10.2022 | 0 |
| 15.10.2022 | 0 |
| 22.10.2022 | 0 |
| 29.10.2022 | 0 |
| 05.11.2022 | 0 |
| 12.11.2022 | 0 |
| 19.11.2022 | 0.10 |
| 26.11.2022 | 0.10 |
| 03.12.2022 | 0 |
| 10.12.2022 | 0.10 |

Table 16: Mass concentration (γ) of ammonium ion in the river Sava for the period between 24.9. and 10.12.2022.

Mostly, the mass concentration of ammonium ions was 0 mg/L. The concentration of NH4+ ions was O,10 mg/L on the 19.11.2022, 26.11.2022 and 10.12.2022 (Table 16).

## TOTAL HARDNESS

The hardness of water depends mainly on the bedrock through which it flows. The term total hardness roughly refers to the concentration of metal ions, mainly calcium and magnesium. Increased concentrations of calcium and magnesium salts increase the alkalinity and hardness of water. Rainwater is considered extremely soft water and has values close to 0od (German hardness level --> 1od = 10 mg of calcium oxide per liter). While tap water can exceed the value of 20+d. The main problem with hard water is limescale. (1 drop=17.8 mg/L CaCO3).

Water hardness is generally defined as soft if the value of metal ions in it is less than 231.4 mg/L. If this value is between 231.4 and 480.6 mg/L, the water is medium hard. If the content of these ions is between 480.6 and 658.6 mg/L, the water is hard. If this value is greater than 658.6 mg/L, we define this water as very hard water.

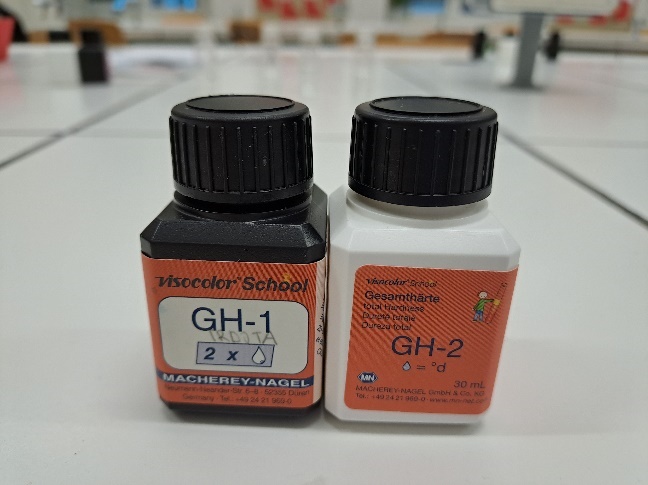


Figure 45: Chemicals used to measure total hardness.

### THE EXPERIMENT PROCEDURE

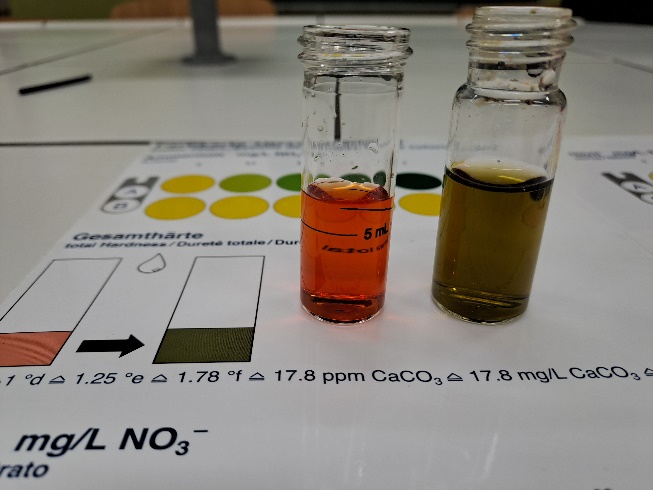
1. Using a small measuring cylinder, we measured 5 ml of the sample into the cuvette.   
2. We added 2 drops of reagent GH-1 and closed the cuvette with a cap.   
3. The cuvette was gently stirred, and the water sample turned red. (If the sample turned green, this would mean that the water contains no or very low concentrations of the elements that affect hardness).   
4. The GH-2 reagent bottle was held at right angle and the reagent was added to the sample cuvette in drops while slowly stirring until there was a noticeable change in colour to green.   
5. When adding GH-2 reagent, we counted the number of drops added to the sample until the colour of the sample changed and converted the results by multiplying the number of drops by 17.8.

Figure 46: Overall hardness measurement.

### LAKE BLOKE

|  |  |
| --- | --- |
| Date of sampling | Total hardness [mg/L] |
| 24/09/2022 | 267.0 |
| 01.10.2022 | 267.0 |
| 08.10.2022 | 267.0 |
| 15/10/2022 | 267.0 |
| 22/10/2022 | 302.6 |
| 29/10/2022 | 284.8 |
| 05.11.2022 | 302.6 |
| 11/12/2022 | 267.0 |
| 11/19/2022 | 302.6 |
| 26/11/2022 | 302.6 |
| 03.12.2022 | 284.8 |
| 10/12/2022 | 267.0 |
| 17/12/2022 | 249.2 |

Table 17: Amount of total hardness in Lake Bloke for the period between 24.9. and 17.12.2022.

At the time of the measurements, the hardness value in Lake Bloke was between 249.2 and 302.6 mg/L. Most of the time the value was 267.0 mg/L. On 22.10., 5.11. and 13.11. and on 26.12.2022 it reached a maximum concentration of 302.6 mg/L. On 3.12.2022, the water hardness in Lake Bloke was 284.8 mg/L. The water was softest on 17.12.2022, when the hardness value was 249.2 mg/L. The water in Lake Bloke is medium hard.

### LAKE PODPEČ

|  |  |
| --- | --- |
| Date of sampling | Total hardness [mg/L] |

|  |  |
| --- | --- |
| 24/09/2022 | 231.4 |
| 01.10.2022 | 195.8 |
| 08.10.2022 | 231.4 |
| 15/10/2022 | 231.4 |
| 22/10/2022 | 231.4 |
| 29/10/2022 | 249.2 |
| 05.11.2022 | 195.8 |
| 11/12/2022 | 231.4 |
| 11/19/2022 | 249.2 |
| 26/11/2022 | 213.6 |
| 03.12.2022 | 231.4 |
| 10/12/2022 | 267.0 |
| 17/12/2022 | 249.2 |

Table 18: Amount of total hardness in Lake Podpeč for the period between 24.9. and 17.12.2022.

The average value for the hardness of Lake Podpeč is 231.4 mg/L. The lowest total hardness value was found on 01.10.2022 and 05.11.2022 (195.8 mg/L), while the highest total hardness content was found in the water sample on 10.12.2022 (267.0 mg/L). Lake Podpeč borders between hard and soft water.

### LAKE KOČEVJE

|  |  |
| --- | --- |
| Date of sampling | Total hardness [mg/L] |

|  |  |
| --- | --- |
| 05.10.2022 | 284.8 |
| 12/10/2022 | 284.8 |
| 19/10/2022 | 284.8 |
| 26/10/2022 | 284.8 |
| 05.11.2022 | 249.2 |
| 11/12/2022 | 302.6 |

Table 19: Amount of total hardness in Lake Kočevje for the period between 5.10. and 12.11.2022.

The average value of the water hardness of Lake Kočevje was 281.8 mg/L. In the month of November 2022, the concentration of total hardness increased (Table 19).

### SAVA

|  |  |
| --- | --- |
| Date of sampling | Total hardness [mg/L] |

|  |  |
| --- | --- |
| 24/09/2022 | 195.8 |
| 01.10.2022 | 160.2 |
| 08.10.2022 | 178.0 |
| 15/10/2022 | 178.0 |
| 22/10/2022 | 178.0 |
| 29/10/2022 | 195.8 |
| 05.11.2022 | 178.0 |
| 11/12/2022 | 195.8 |
| 11/19/2022 | 195.8 |
| 26/11/2022 | 195.8 |
| 03.12.2022 | 195.8 |
| 10/12/2022 | 195.8 |

Table 20: Amount of total hardness in the river Sava for the period between 24.9. and 10.12.2022.

The hardness value in the Sava was 195.8 mg/L most of the time for the majority of the samples tested (this was the highest total hardness value). According to certain values of total hardness, the Sava belongs to soft waters.

## pH

pH is a measure of the concentration of oxonium ions in a solution, and thus a measure of its acidity or basicity. pH is expressed as a number between 0 and 14. Solutions with a pH less than 7 are acidic, solutions around 7 are neutral, and solutions above 7 are basic. The more acidic the solution, the lower its pH value. The more basic the solution, the higher its pH value. In most natural waters, pH is related to the balance of carbon dioxide, hydrogen carbonate and carbonate and the associated hardness of the water. Soft waters have a lower pH, while hard waters have a higher pH. The pH value decreases slightly with increasing temperature. Hydrogen ion concentrations can affect human health either directly or indirectly. Direct exposure to extremely high or low pH causes eye, mucous membrane and skin irritation and tissue damage.

Figure 47: pH strips used to measure pH.

### THE EXPERIMENT PROCEDURE

Universal indicator paper for measuring pH was dipped in water, soaked for a while, and then the pH of the water samples was read on the pH scale, thereby inferring the pH of a certain body.

Figure 48: pH measurement.

### LAKE BLOKE

|  |  |
| --- | --- |
| Date of sampling | pH |
| 24/09/2022 | 7 |
| 01.10.2022 | 7 |
| 08.10.2022 | 7 |
| 15/10/2022 | 7 |
| 22/10/2022 | 7 |
| 29/10/2022 | 8 |
| 05.11.2022 | 7 |
| 11/12/2022 | 7 |
| 11/19/2022 | 7 |
| 26/11/2022 | 7 |
| 03.12.2022 | 7 |
| 10/12/2022 | 7 |
| 17/12/2022 | 7 |

Table 21: pH value in Lake Bloke for the period between 24.9. and 17.12.2022.

The pH value of all samples of Lake Bloke was 7. The lake belongs to neutral waters.

### LAKE PODPEč

|  |  |
| --- | --- |
| Date of sampling | pH |

|  |  |
| --- | --- |
| 24/09/2022 | 7 |
| 01.10.2022 | 7 |
| 08.10.2022 | 7.5 |
| 15/10/2022 | 8 |
| 22/10/2022 | 8 |
| 29/10/2022 | 8 |
| 05.11.2022 | 8 |
| 11/12/2022 | 8 |
| 11/19/2022 | 8 |
| 26/11/2022 | 8 |
| 03.12.2022 | 8 |
| 10/12/2022 | 8 |
| 17/12/2022 | 8 |

Table 22: pH value in Lake Podpeč for the period between 24.9. and 17.12.2022.

The predominant pH value in the water samples from Lake Podpeč was 8. Lake Podpeč belongs to neutral waters.

### LAKE KOČEVJE

|  |  |
| --- | --- |
| Date of sampling | pH |

|  |  |
| --- | --- |
| 05.10.2022 | 7 |
| 12/10/2022 | 6.5 |
| 19/10/2022 | 7 |
| 26/10/2022 | 7 |
| 05.11.2022 | 7 |
| 11/12/2022 | 7.5 |

Table 23: pH value in Lake Kočevje for the period between 5.10. and 12.11.2022.

The pH value in Lake Kočevje varied between 6.5 and 7.5. It reached its lowest value on 12.10.2022, and its highest on 12.11.2022. Lake Kočevje belongs to slightly acidic waters.

### SAVA

|  |  |
| --- | --- |
| Date of sampling | pH |

|  |  |
| --- | --- |
| 24/09/2022 | 8 |
| 01.10.2022 | 8 |
| 08.10.2022 | 7 |
| 15/10/2022 | 8 |
| 22/10/2022 | 8 |
| 29/10/2022 | 8 |
| 05.11.2022 | 7 |
| 11/12/2022 | 8 |
| 11/19/2022 | 7 |
| 26/11/2022 | 7 |
| 03.12.2022 | 7.5 |
| 10/12/2022 | 7.5 |

Table 24: pH value in the river Sava for the period between 24.9 in 10.12.2022.

The pH values in the Sava water samples were between 7 and 8. The river Sava belongs to neutral to slightly alkaline waters.

## TEMPERATURE

The water temperature in a body of water depends mainly on the temperature of the area, the amount of precipitation and the flow rate of the body of water. It is normal for the temperature to vary in proportion to the ambient temperature, so it varies significantly throughout the year. Temperatures are lower in colder months and higher in warmer months. Temperature has a great influence on the properties of water, especially on the water body as an ecosystem. It has a decisive influence on the development of flora and fauna in the water, as well as on the development of various microorganisms.

Figure 49: The thermometer we used to measure the temperature.

### THE EXPERIMENT PROCEDURE

The thermometer was soaked in water and waited for the alcohol in the thermometer to stabilise. Then we read the temperature. We repeated this process 3 times.



Figure 50: Temperature measurement.

### LAKE BLOKE

|  |  |
| --- | --- |
| Date of sampling | Temperature [°C] |
| 24/09/2022 | 13 |
| 01.10.2022 | 15 |
| 08.10.2022 | 16 |
| 15/10/2022 | 16 |
| 22/10/2022 | 13 |
| 29/10/2022 | 16 |
| 05.11.2022 | 12 |
| 11/12/2022 | 11 |
| 11/19/2022 | 8 |
| 26/11/2022 | 5 |
| 03.12.2022 | 2 |
| 10/12/2022 | 6 |
| 17/12/2022 | 4 |

Table 25: Temperature of Lake Bloke for the period between 24.9. and 17.12.2022.

The measured water temperature of Lake Bloke was 13 °C on 24.9.2022. A week later, the temperature rose to 15 °C. The temperature rose further after that date to 16°C on 8.10.2022. This temperature was the same a week later. The temperature then dropped to 13 °C on 22.10.2022 and then rose again to 16 °C on 29.10.2022. After 5 of November temperatures dropped, with the lowest temperature on 17.12.2022 (4 °C).

### LAKE PODPEČ

|  |  |
| --- | --- |
| Date of sampling | Temperature [°C] |

|  |  |
| --- | --- |
| 24/09/2022 | 13 |
| 01.10.2022 | 14 |
| 08.10.2022 | 14 |
| 15/10/2022 | 13 |
| 22/10/2022 | 14 |
| 29/10/2022 | 13 |
| 05.11.2022 | 10 |
| 11/12/2022 | 10 |
| 11/19/2022 | 10 |
| 26/11/2022 | 9 |
| 03.12.2022 | 7 |
| 10/12/2022 | 5 |
| 17/12/2022 | 2 |

Table 26: Temperature in Lake Podpeč for the period between 24.9. and 17.12.2022.

The temperature in Lake Podpeč was between 13 and 14 °C from 24.9.2022 to 29.10.2022. On 24.9.2022, 15.10.2022 and 29.10.2022 it was 13 °C, and on 8.10.2022 and 22.10.2022 it was 14 °C. Afterwards, lower water temperatures are recorded, the lowest being 2 °C on 17.12.2022.

### LAKE KOČEVJE

|  |  |
| --- | --- |
| Date of sampling | Temperature [°C] |

|  |  |
| --- | --- |
| 05.10.2022 | 18 |
| 12/10/2022 | 20 |
| 19/10/2022 | 17 |
| 26/10/2022 | 19 |
| 05.11.2022 | 14 |
| 11/12/2022 | 11 |

Table 27: Temperatures of Lake Kočevje for the period between 5.10. and 12.11.2022.

The temperature of Lake Kočevje was 18°C on 5.10.2022. Then, on 12.10.2022, the temperature rose to 20°C. On 19.10.2022, the temperature dropped to 17°C, then on 26.10.2022, it rose again to 19°C. Afterwards, the temperature started to drop again. On 5.11.2022 it reached 14°C and on 12.11.2022 it reached 11°C.

### SAVA

|  |  |
| --- | --- |
| Date of sampling | Temperature[°C] |

|  |  |
| --- | --- |
| 24/09/2022 | 12 |
| 01.10.2022 | 11 |
| 08.10.2022 | 11 |
| 15/10/2022 | 12 |
| 22/10/2022 | 11 |
| 29/10/2022 | 10 |
| 05.11.2022 | 9 |
| 11/12/2022 | 8 |
| 11/19/2022 | 7 |
| 26/11/2022 | 6 |
| 03.12.2022 | 6 |
| 10/12/2022 | 6 |

Table 28: Temperature in the river Sava for the period between 24.9. and 10.12.2022.

On 24.9. and 15.10.2022, the water temperature in the Sava was 12 °C, making it the maximum recorded temperature. From the second half of October to the second half of December 2022, the water temperature decreased to 6 °C, representing the minimum recorded water temperature of the Sava.

## ION CHROMATOGRAPHY

Chromatography is a method of analytical chemistry for separating mixtures. The sample travels through the mobile phase with solvent flow through the stationary phase. In the stationary phase, there is a substance that provides resistance to the components of the sample solution. Each component of the mixture has a separation rate, allowing us to determine the components making up the original mixture.

Figure 51: Ion chromatograph used to perform ion chromatography. (taken by Gregor Marolt)

### THE PROCESS

A 0.1 molar KOH solution is pumped from the cartridge through a pump and used to push the analytes through the column with the resulting hydroxide ions. We insert our sample into the solution via the injector. The sample solution travels into the column. The column contains a whole cluster of cations to which the analytes bind. Negative ions bind the weakest once, then negative twice, and so on. The retention time increases with the strength of the bond between the analyte and the cations in the column. The washed analytes are passed through the detector. The detector measures the magnitude of the current flowing between two platinum electrodes. As analysts arrive, the size of the flow increases. With the help of the detector, the computer equipment draws a graph of the current as a function of time. Several peaks are observed in the graph and the retention time is used to determine which peak represents which analyte. The concentration is calculated by multiplying the constant of the analyte by the area of the peak on the graph. We tested the concentration of chloride, nitrate, nitrite, sulphate and phosphate ions. The first peak was chloride (lowest retention time), second was A picture containing chart

Description automatically generatednitrite, third nitrate, fourth sulphate and last phosphate (highest retention time).

Graph 1: Demonstrates ion chromatography.

### THE RESULTS

The mass concentrations of nitrite and phosphate obtained by ion chromatography are comparable to those obtained by simple reactant tests. Differences in the amount of nitrate can be due to inaccuracy in the readings of simple tests, or to contamination or malfunctioning of the reagent due to improper storage or shelf life.Diagram

Description automatically generated with low confidence

Table 29: Ion chromatography results.

# DISCUSSION

Based on the results, we can return to the research question "What is the quality of bathing waters in Slovenia?". We concluded that the bathing water quality is quite good and that the lakes and rivers surveyed are suitable for swimming.

NITRITES

In all observed water bodies, the values of nitrite ions corresponded to the limit set by Slovenian legislation and did not exceed the value of 0.50 mg/L. The lowest values were determined in the samples of the river Sava and Lake Kočevje, where the value did not exceed 0.02 mg/L, with the exception of the sample of the Sava on December 10, 2022, when we measured 0.03 mg/L. We can therefore conclude that there were no large, cultivated areas in the vicinity of Lake Kočevje and the river Sava, or that the land was not fertilised at that time. We further conclude that there is no discharge of urban wastewater into the water body. Highest values were measured in samples from Lake Bloke and Lake Podpeč, where values rose three times to the maximum concentration of nitrite ions still allowed under Slovenian legislation. We can conclude that this is due to fertilisation of the agricultural land, which is abundant in the surroundings of both lakes. However, there are no municipal discharges into the two lakes.

NITRATES

In all observed water bodies, the values of nitrate ions were quite low compared to the limits of Slovenian legislation. Lowest values of this ion were measured in Lake Kočevje, where the value did not exceed 1.00 mg/L. We conclude this is due to the lack of arable land around the lake. As a result, there is no fertilisation with fertilisers containing high amounts of nitrogen. Maximum measured value was 7.50 mg/L in Lake Podpeč. We conclude this is due to the large amount of agricultural land along the lake. At the time when the nitrate ion was at its highest, fertiliser was most likely being applied. Lake Bloke and the river Sava had similar nitrate ion values, which did not exceed 2.50 mg/L. We expected nitrate levels in the Sava to be higher, as there is considerable agricultural land along the river.

PHOSPHATES

In all observed water bodies, the values of phosphate ions in the samples did not exceed 1 mg/L. Closest to this were the Sava and Lake Bloke, where we measured the highest amount of phosphate ions. We can conclude that at this time, fertilisers were applied to the agricultural areas close to both water bodies and that rain fell, thereby leaching the fertilisers into the water that flowed into the lake. Phosphate ions have not been determined in Lake Kočevje. Even if fertiliser had been applied to agricultural land and it had not rained, the fertilisers would not have leached into the soil and consequently into the lake. No wastewater is discharged into any of the water bodies.

AMMONIUM

In all observed water bodies, the values of ammonium ions were quite low compared to the limits of Slovenian legislation. Very low values of ammonium ions were determined in all waters. We therefore conclude that there have been no major discharges of manure and fertilisers into water bodies. All the lakes also have a rich diversity of aquatic life, meaning that ammonium ion levels are low enough not to threaten the life of aquatic organisms. In Lake Podpeč and Lake Kočevje, the measurement results were consistent (always 0.10 mg/L).

HARDNESS

Lake Bloke and Kočevje have the highest hardness, followed by Lake Podpeč in terms of values. The river Sava has a noticeably lower hardness. We conclude that the reason for this difference is the different rock composition of the soil. Limestone (CaCO3) and dolomite (CaMg(CO3)2) dominate along the lakes of Kočevje, Bloke and Podpeč. Together, these two rocks contain high levels of calcium and magnesium ions, increasing the strength of the water. Sava's bedrock is not as rich in these ions, so the water tends to be softer.

PH

All pH values were in the neutral range. The pH was very similar in all the water bodies we studied. The lowest pH of all samples was determined in the water sample from Lake Kočevje. At Lake Bloke, only one exception occurred, when the pH was 8. On the day we took the sample, the weather was sunny and the water was warm, so people were bathing in the water. This could result in a higher pH value. The values for Lake Podpeč and the river Sava are assumed to differ due to the presence or low concentrations of artificial fertilisers in the individual samples. We assume that better results would be obtained if we could measure the whole year and compare the results according to the farming periods of the year. We measured during late autumn and early winter, thus not very comparable with the rest of the year.

TEMPERATURE

Water temperature in all observed water bodies decreased as the atmosphere became colder. The largest temperature difference was in Lake Bloke, while the smallest was in Lake Kočevje. In the warmer months, the Sava was the coldest, as it is the most flowing. Highest temperature (20°C) was measured in Lake Kočevje, while lowest temperature was 2°C in Lake Bloke and Lake Podpeč.

We refuted and confirmed the following hypotheses.

*Hypothesis 1: The Sava is more suitable for bathing than lakes due to its higher water flow.*

We refuted this hypothesis, as the values of the parameters measured in the Sava are completely comparable to the values of the parameters in the lakes. All bodies of water are similarly suitable for swimming.

*Hypothesis 2: Water temperature will be higher in standing bodies of water (lakes) compared to the Sava*.

This hypothesis is partly true. In the warmer months, the temperature in the Sava was significantly lower than the water temperature in all three lakes. In the colder months, the water temperature in the Sava was higher than the water temperature in Podpeška and Bloška jezera. We therefore conclude that the temperature amplitude in the Sava is smaller than the temperature amplitude of the lakes.

*Hypothesis 3: Nitrate concentration influences nitrite concentration. Where higher concentrations of nitrate are found, higher concentrations of nitrite will occur as well.*

This hypothesis is true. In Lake Podpeč, the amount of nitrite and nitrate is significantly higher, while the concentrations of both ions in Lake Kočevje are very low. In Lake Bloke and the river Sava, these ions are in similar proportions.

*Hypothesis 4: Nitrate concentrations in water are higher in the river Sava than in lakes. This could be due to the proximity of cultivated areas, extending to the river in some places.*

This hypothesis was refuted. The nitrate concentration in Lake Podpeč is much higher than that in the Sava. The nitrate concentrations in the Sava and Lake Bloke are approximately the same. However, the nitrate concentration in Lake Kočevje is indeed lower than the concentration of the ions in the Sava.

*Hypothesis 5: Ammonium ion levels will be increased in standing bodies of water due to poorer treatment systems, as it enters the water from animal excrement.*

We confirmed this hypothesis. The concentration of ammonium ions is not high in any of the water bodies, but it is indeed higher in stagnant waters than in the Sava.

*Hypothesis 6: Phosphate concentration is increased in the Sava due to the proximity of settlements and industrial plants.*

We confirmed this hypothesis. The concentration of phosphates is indeed the highest in the Sava.

*Hypothesis 7: Ph will be higher in lakes than in the Sava.*

This hypothesis was refuted. pH is comparably high in all water bodies. In the Sava, the pH is slightly lower than in Lake Podpeč, but slightly higher than in lakes Kočevje and Bloke.

*Hypothesis 8: The hardness and pH of water are proportionally related to each other, as the pH of water affects its hardness.*

We refuted this hypothesis. We did not find any relationship between pH value and water hardness.

# CONCLUSIONS

Bathing and recreation in natural bathing waters is a common and quality way to spend leisure time, especially in the summer months. It is important that the quality of the water we bathe in is good and that it is clean. Otherwise, the water can have a negative impact on our health. If the water is not clean, skin problems and rashes often occur. Not only is such water unsuitable for bathing, it is equally unsuitable for the organisms that live in it. Ecosystems where water contains a lot of harmful substances are changing and losing diversity.

Natural waters often contain various ions that enter the water as a result of fertilization of nearby agricultural land. Fertilizers high in nitrogen are leached into the water in rainwater, resulting in high levels of nitrite, nitrate and ammonium ions.

In our research, we investigated how many of these ions are found in the bathing water we often bathe in ourselves. We were curious to know if these waters are suitable for bathing. We compared the results in different bodies of water and tried to explain why some bodies of water have higher levels of a specific ion. Agricultural land near the water bodies was a big factor.

In the end, we concluded that all the bodies of water we examined were clean enough to swim in. Although there were some differences between the water bodies, all of them are suitable for swimming. All values were within the limits of Slovenian legislation and guidelines.

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