Basic Properties
of the Kamniška Bistrica River

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ABSTRACT

We conducted basic GLOBE measurements (temperature of air and water, electrical conductivity, pH) on the Kamniška Bistrica River, which flows near our school. When we found that the pH of the water was slightly basic, we expanded our range of measurements by also measuring the total hardness. After the measurements were complete, we started looking for connections between them and explanations for those connections.

We found out that the air and water temperatures were related, but changes in water temperature were smaller than changes in air temperature, which can be explained by its higher specific heat compared to air. The water in Kamniška Bistrica River is hard, which means that a lot of mineral substances are dissolved in it. The electrical conductivity of river water is much higher than the electrical conductivity of distilled water, so the concentration of ions that can contribute to electrical conductivity is high, which is probably also a result of the high hardness of the water. Water pH in the river is slightly basic due to the dissolved carbonate rocks (which we found on the bank and alluvium and tested with the acid test) and is connected to the alkalinity of the water - which we plan to explore further.

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1. Research Question and Hypotheses

When we joined GLOBE and started using the GLOBE protocols in the Kamniška Bistrica River, we first selected the basic measurements of the hydrosphere, air and water temperature, and pH. When we checked the results of the measurements, we found that the river water is slightly basic and not neutral (pH 7), as we expected.

Therefore, the **question** arose: what are the reasons behind the specific pH level of 8 in the Kamniška Bistrica River and what effects could it have on the properties of the water and life in and along the river?

We first started looking for answers in the literature and came across the concept of alkalinity - alkalinity and pH are properties of water that are related, but different. Alkalinity is the measure of the pH buffering capacity of the water, which means a water's resistance to the lowering of pH when acids are added to the water. pH, on the other hand, is the acidity of water. Alkalinity is generated as water dissolves rocks containing calcium carbonate such as calcite and limestone.

When we compared the results of our measurement site with the results of measurements at two sites higher up the river, we found that they measured similar pH there. Even after talking with school staff in Kamnik, who also carry out measurements on the same river, we found similar results. Based on this and after a general review of what is happening along the river, we concluded that the probability of a basic pH due to human activity is small and it is more likely that the higher pH is the result of the dissolution of carbonate rocks in the soil.

Therefore, we decided to explore more of Kamniška Bistrica and added electrical conductivity and total hardness of the river measurements to our research. Unfortunately, we did not have enough time and opportunity (if we wanted to submit the research paper on time), so we left the second part of the research question (*what effect it could have on the properties of the water and the life in and along the river*) for the next research paper.

We set the following hypotheses:

1. The water in Kamniška Bistrica River is hard.
2. The electrical conductivity of the river water will be much higher than the electrical conductivity of distilled water.
3. The pH of the river water will be slightly basic.
4. Rock samples from riverbanks and alluvium will contain carbonate rocks.

2. Introduction and Review of Literature

2.1 The Hydrosphere and the Earth System

Figure 1. *The Earth System*

The Earth system consists of the atmosphere (air), hydrosphere (water) and lithosphere, which includes pedosphere (soil, land) and biosphere (life). The processes in the system are interacting physically, chemically, and biologically. Changing any part of the Earth system, such as water chemistry or water transparency can affect the rest of the system. GLOBE's Hydrosphere Investigation is important – we use it to document the chemical and physical characteristics of our water bodies, which are important to life, we also document when and where changes in our Earth's water bodies are found.

The hydrologic (water) cycle actively connects all parts of the Earth system. When the Sun heats the water in the oceans, rivers, lakes, soils, and vegetation, it causes water evaporation – water transforms from a liquid to a gaseous aggregate state and moves from water bodies into the atmosphere. Water vapor then cools and turns into liquid water or ice to become clouds. When water droplets or ice crystals get large enough, they fall back to the surface as rain or snow.

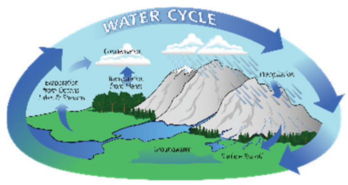


Figure 2. *The Water Cycle*

Completely pure water rarely occurs in nature because water is a **good solvent.** As it travels through the hydrologic cycle, rain, and snow capture aerosols from the air. Acidic rain slowly dissolves rocks, placing dissolved solids in water and when it percolates into the ground, more minerals dissolve in the water. Dissolved or suspended impurities determine water's chemical composition. By studying changes in the quality and composition of water bodies, we are also gathering clues about changes in other parts of the Earth system.

The hydrology investigation area focuses on water and water bodies. The hydrology protocols include water temperature, transparency, pH, dissolved oxygen, either conductivity or salinity, alkalinity, nitrates, as well as a documentation of the macro-invertebrates found in fresh water [1] [2] .

2.2 The River Kamniška Bistrica

Figure 3. *The River Spring*

Kamniška Bistrica is a river in central Slovenia. The river is 33 km long and originates in a karst spring at an altitude of 623 m at the beginning of the valley of the same name. In the central part, i.e. from Kamnik to Domžale in length of over 17 km, it is almost completely urbanized. In this part, Kamniška Bistrica mostly flows in a rigidly regulated channel.

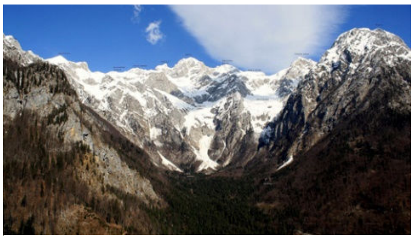


Figure 4. *Kamniška Bistrica* V*alley, upper end*

The valley of Kamniška Bistrica is a glacially formed alpine valley on the southern side of the Kamniška-Savinja Alps. It is 7.5 km long and 3.4 km wide. The peaks of Krvavec, Kalško greben, Grintovec, Skuta, Turska gora, Brana, Planjava, Ojstrica, the Velika planina and Kamniški vrh are leaning over it. The valley is steep and initially narrow, in the shape of the letter V, which is why it is difficult to access and consequently sparsely populated [3] - [5].

Kamniška Bistrica is the largest Slovenian torrent, which means that it is very rapid, especially during the melting snow and rains, when torrential waters flow into it from the slopes of the valley. The torrential character is manifested by a very large difference between low and high flows, in the ratio of approximately 1:300 [6] [7].

The river carries rocks from the upstream areas of the basin. The sharp edges of gravel that crumble from the steep rock walls is captured by the water and rolled along the bottom, where they rub against each other and grind each other down. This creates pebbles of different sizes and shapes. Pebbles from a wide variety of sedimentary rocks and, to a lesser extent, magmatic rocks can be found on the gravel pits below Homški hrib. The mountainous part of the watershed is mostly made of Triassic and partly Jurassic predominantly carbonate rocks (limestone and dolomite) [8].

The river is also called the salmonid river, as it has a fast current and a high oxygen content. It belongs to the Sava basin and flows into it a little before the Ljubljanica River. Its watershed includes Korošica, Bistričica and Pšata as right tributaries and Kamniška bela, Nevljica and Rača as left tributaries. The upper course is very different from the middle and lower course: in the upper course it is a real raging mountain river with a large precipice, while in the middle and lower course it flows on a plain on gravelly debris through an urbanized area. Most of the surface on which the river flows are made of carbonate rocks (limestone, dolomite, red quartz ...) Like a real karst river, it also dries up from time to time, especially during periods of severe drought [9].

The river first has a large meander through coniferous forests, then flows into the bottom of the glacial valley. It flows along a wide gravel terrace towards Kamnik, where it joins Nevljica and continues through a continuous area of settlements in the vicinity of Kamnik and Domžale. Rača flows into it from the left. It flows over a wide flood plain, where the Domžale sewage treatment plant is located. It joins the Pšata and flows into the Sava, shortly before the confluence with the Ljubljanica [3] - [5].

Kamniška Bistrica is extremely watery and has a rain-snow regime, which means that water levels are high in autumn and spring, during the melting snow and autumn rains, and low in summer and winter. During the heavy rains, due to a high water level, floods can occur. Nowadays its flood plains are densely populated, which is a big problem. To prevent floods, many transverse barriers and dams were built, the banks were arranged in many places, the water is also drained into artificial riverbeds, which were built to supply water to mills and sawmills (11 mills) [10].

On August 4, 2023, Kamniška Bistrica overflowed its banks due to heavy and long-lasting rains. The water spilled hundreds of meters from the riverbed, flooding several houses, closing roads, and damaging a bridge on an important access road to the city [11] [12].

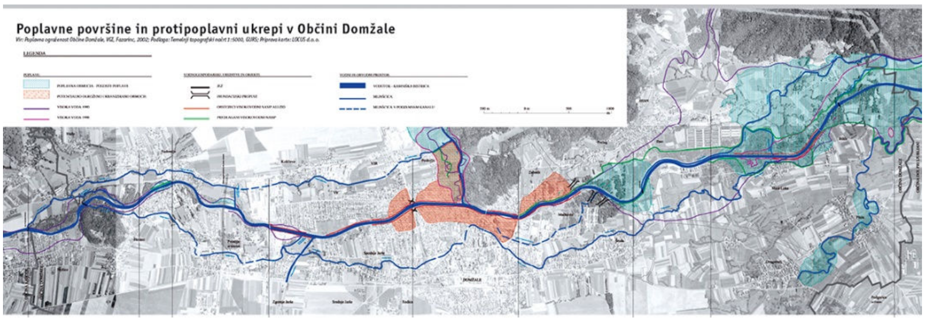


Figure 5. *Flood Areas and Anti-flood Measures in the Municipality of Domžale*

Figures 6 and 7. *Floods in Domžale, August 4, 2023*

Today, the entire riverbed of Kamniška Bistrica is narrowed and levelled, and the former flood plains are urbanized. Climate changes in recent decades, and demands for new and more restrictive regulations, have increased the torrential character of the watercourse, while at the same time worsening the flood safety of downstream areas.

The river has always been extremely economically important, originally supplying mills and sawmills. Its high water level and fall were used to generate hydropower. At the same time, it also feeds the groundwater and thus greatly contributes to the supply of drinking water in the entire Ljubljana basin. Hydropower was also the reason for the development of industrial infrastructure and larger towns along its banks. In the previous century, dense industry heavily polluted the river with discharges. In the lower reaches it was considered a "dead river". Fortunately, many water treatment plants were installed at the turn of the millennium, e. g. in Študa, between Domžale and Kamnik, and introduced many environmental protection laws, which require factories to purify discharged water. Nowadays, the river is much better cleaned, but pollution is still a big problem. In the summer, there is little water in the riverbed, so the self-cleaning ability of the river is reduced, and it is more difficult to purify itself. It is also polluted during floods because of wastewater from settlements and toxic substances, pesticides [6] ...

A more detailed analysis of the algae would show that the river is more heavily polluted, especially in the lower part. The pebbles are densely overgrown with a layer of algae that feed on nutrients dissolved in the water. A clean river contains less nutrients, so there is less algae [13].

In the middle and lower reaches, the watercourse has been greatly transformed, but is still overgrown with forests. Even since the river has been cleaner, the populations of fish and other living organisms have been restored. The most common species are brown trout, chub, pike, grayling ... Today, they are most threatened by the loss of living space and the lack of water in the main riverbed due to excessive drainage into artificial lateral riverbeds.

Kamniška Bistrica is therefore an economically and environmentally very important river, which has a great influence on its surroundings, natural or urbanized. It enabled people to exist and develop in this area. They adapted it to their needs, which often has consequences even today (e. g. floods). A serious problem is pollution, which began with the development of the surrounding industry, but is now much more under control thanks to sewage treatment plants and environmental laws.

2.3 GLOBE Hydrosphere Protocols

With GLOBE protocols we obtain accurate data if we follow all the instructions. In the Earth system "everything is connected to everything else," so often, we need to follow more than one protocol, because different characteristics of water influence each other. Through the GLOBE Hydrosphere Investigation Protocols, we can also answer many questions regarding the waters near our school [14].

Figure 8. *GLOBE Data Entry Logo*

2.3.1 Air Temperature Protocol

Figure 9. *Thermometer*

The Atmosphere is part of the Earth System. It's an extremely thin sheet of air extending from the surface of the Earth to the edge of space. Air temperature measures the heat in the air. It's warmest at the surface and decreases with height. The unequal heating of the Earth's surface drives air and ocean circulation and causes climate to vary by latitude. Fluid properties are constantly changing with time and location. We call this change the weather. Air temperature impacts the types of plants and animals that live in a certain location and soil formation [15].

2.3.2 Water Temperature Protocol

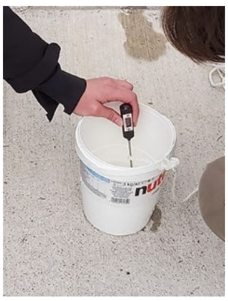


Figure 10. *Water Temperature*

The measurement of water temperature determines how hot or cold the water is. Sudden increases or decreases of water temperature are unusual. Water has a higher heat capacity (specific heat) than air, thus it heats and cools more slowly.

Water temperature is sometimes called a master variable because almost all properties of water, as well as chemical reactions taking place in it, are affected by it. Water temperature is also an important variable determining what organisms can live in a water body [14].

2.3.3 Water Alkalinity Protocol

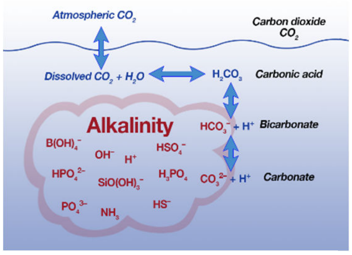


Figure 11. *Carbonate System Ions and Molecules*

Alkalinity and pH are properties of water that are related, but different. Alkalinity is the measure of the pH buffering capacity of the water, that means a water's resistance to the lowering of pH when acids are added to the water. pH, on the other hand, is the acidity of water.

Alkalinity is generated as water dissolves rocks containing calcium carbonate such as calcite and limestone. When a lake or stream has low alkalinity, typically below about 100 mg/L as $CaCO_3$, a large influx of acids from a big rainfall or rapid snowmelt event could (at least temporarily) drop the pH of the water to levels harmful for amphibians, fish, or zooplankton.

When water has high alkalinity, we say that it is *well buffered* and is less sensitive to chemical changes that could result in a change in acidity. It resists a decrease in pH when acidic water, such as rain or snowmelt, enters it. Lakes and streams in areas rich in limestone bedrock will tend to have a higher alkalinity than those in regions with non-carbonate bedrock [14].

Water Hardness

Figure 12. *Total Hardness*

Water hardness is caused by dissolved mineral substances. Different substances are dissolved in drinking water. Their amount and type depend on the area where the water originates, on the chemical composition of the substrate over, and through, which the water flows before reaching the surface. The more natural water dissolves them from soil and rocks, the harder it is.

Water hardness consists of temporary and permanent hardness. Temporary hardness of water can be removed by boiling. When water is heated, calcium and magnesium hydrogen carbonates are converted into insoluble carbonates. The excreted carbonates are so-called scale or limescale, which accumulates rapidly in pipes, steam boilers, drum washing machines, etc. at 60 °C and above. Hard water also reduces the power of washing powders and other detergents. All other mineral substances that are not excreted during boiling belong to permanent hardness (sulfates, chlorides, sodium carbonate, etc.) [16].

Figure 13. *Limescale*

Water hardness is most often expressed in German hardness levels (°dH), where one level means a content of 10 mg of CaO per liter of water or 17.8 mg $CaCO_3$ per liter of water [17].

°dH	mg $CaCO_3$/L (ppm)	Classification
0-3	0-54	Very soft
4-7	71-125	Soft
8-11	142-196	Medium hard
12-16	214-285	Fairly hard
17-29	303-516	Hard
more than 29	> 516	Very hard

Table 1. Total Hardness Scale

2.3.4 Electrical Conductivity Protocol

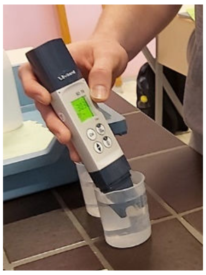


Figure 14. *Electrical Conductivity*

Electrical conductivity measures the capacity of water to transmit an electrical current. This capacity is directly related to the concentration of salts or impurities in the water and depends on the presence of ions in the water: on their concentration, mobility and charge, and on the temperature of the water at the time of measurement. Solutions of inorganic substances are mostly good conductors, while molecules of organic substances that do not dissociate in water conduct electric current poorly or not at all. The unit for electrical conductivity is micro-Siemens per cm (µ S/cm). Seawater has an electrical conductivity of about 50,000 µS/cm, while rainwater has an electrical conductivity of 5–30 µS/cm.

The amount of mineral and salt impurities in the water is called the total dissolved solids (abbreviated TDS) and we use electrical conductivity as an indirect measure to find the TDS of water. Significant changes in conductivity can be an indication of pollution or a discharge into a water body.

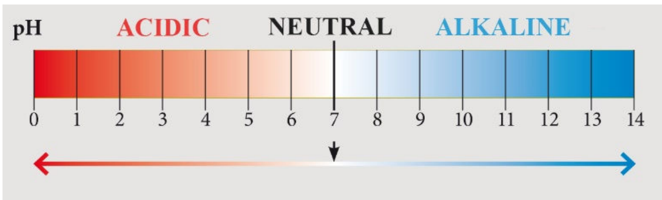
Temperature also affects electrical conductivity: the higher the water temperature, the higher the electrical conductivity would be. This is why temperature readings are also taken when measuring electrical conductivity [14].

2.3.5 Water pH Protocols

Figure 15. *pH*

The concentration of the hydrogen ion (H^+) activity in a solution determines the pH**.**

pH is reported in units from 0-14, with 0 as the most acidic and 14 as the most basic, 7 is defined as neutral pH. Each number represents a 10x change in the acidity or alkalinity of the water.



[18]

Figure 16. *pH Scale*

Water pH affects most chemical and biological processes that take place. The pH affects the solubility (amount that can be dissolved in water) and biological availability of nutrients. It also determines the degree to which potentially toxic materials, such as heavy metals, are soluble.

The pH of a water body can be measured using either a pH meter or pH paper. The accuracy of either method depends on the electrical conductivity of the water (it needs to be at least 200 µS/cm for these methods to report accurately) [14].

2.3.6 Other Hydrosphere Protocols

Water Transparency Protocols – it measures depth of light penetration into the water, which depends on the amount of suspended particles – organic (phytoplankton and algae) or inorganic (sediments), as well as other dissolved impurities such as organic or inorganic carbonates. These particles limit the penetration of light through the water column and contribute to both the color and the transparency of the water.

Dissolved Oxygen Protocol – Aquatic animals, such as fish, and the zooplankton they feed on, breathe the oxygen molecules dissolved in the water. Without sufficient levels of dissolved oxygen in the water, aquatic life suffocates. The amount of oxygen gas that is soluble in water is dependent on many factors, including water temperature, atmospheric pressure, and salinity. Colder water can dissolve more oxygen than warmer water. Water at higher elevations holds less dissolved oxygen since the atmospheric pressure is lower. And as salinity increases, the solubility of oxygen decreases.

Water Salinity Protocol - Water in seas and oceans is salty and has a much higher dissolved solids content than in freshwater lakes, streams, and ponds. Salinity is a measure of that saltiness and is expressed in parts of impurity per thousand parts waters. The average salinity of Earth's oceans is 35 parts per thousand (35 ppt).

Water Nitrate Protocol – Plants in both fresh and saline waters require three major nutrients for growth: carbon, nitrogen, and phosphorus. Nitrogen exists in water bodies in numerous forms: dissolved molecular nitrogen (N_2), ammonium (NH_4^+), nitrite (NO_2^-), nitrate (NO_3^-) and other organic compounds. Water nitrate is often a limiting factor for plant growth. Excessive nitrogen in a water body can cause overgrowth of plant life, ultimately creating poor oxygenation for aquatic organisms.

Freshwater Macroinvertebrates Protocol – Macroinvertebrates play a crucial role in the ecosystem – they provide an essential link in the food chain and are the source of food for many larger animals. Some also help to filter water. Macroinvertebrate samples allow us to estimate biodiversity, examine the ecology of the water body and explore relationships between water chemistry measurements and organisms at the Hydrosphere Study Site.

Mosquito Habitat Mapper Protocol – Mosquitos are food sources for many species of birds, amphibians, and reptiles. Male mosquitoes are pollinators and so they help to make fruits and vegetables. However, some species transmit diseases that impact people including malaria, Chikungunya virus, dengue fever, Zika, and West Nile virus. Identifying the breeding areas of mosquitos that are disease vectors for humans is an important component of local disease management and eradication [14].

2.4 ARSO

Figure 17. *ARSO Logo*

The **Slovenian Environment Agency** is the main environmental organisation in the Republic of Slovenia, founded in 2001. The range of duties of this organisation are in the field of monitoring, analysing and forecasting of natural phenomena and processes in the environment and reduction of the danger to people and their property [19].

ARSO owns https://meteo.arso.gov.si/ or www.meteo.si, where we can find current weather conditions and forecasts as well as archived data [20].

2.5 The Acid Test

Figure 18. *Acid Test*

The term "acid test" means placing a drop of diluted hydrochloric acid or vinegar on a rock or mineral and watching for bubbles of carbon dioxide gas being released. The bubbles signal the presence of carbonate minerals such as **calcite** or **aragonite** (both $CaCO_3$), **dolomite** ($CaMg(CO_3)_2$), **magnesite** ($MgCO_3$) or any other carbonate mineral.

The carbon dioxide bubbles on the mineral specimen are evidence that the reaction is taking place:

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + \mathbf{CO_2(g)} + H_2O(l)$$

Many carbonate minerals react with hydrochloric acid. Each of these minerals consists of one or more metal ions combined with a carbonate ion (CO_3^{2-}). The chemistry of these reactions is like the calcite reaction above.

The bubbling release of carbon dioxide gas can be strong or weak because of the type of carbonate minerals present, the amount of carbonate present, the particle size of the carbonate, and the temperature of the acid.

Limestone is composed almost entirely of calcite and will produce a vigorous fizz with a drop of hydrochloric acid.

Dolostone is a rock composed of almost entirely of dolomite. It will produce a very weak fizz when a drop of cold hydrochloric acid is placed upon it, a more obvious fizz when powdered dolostone is tested, and a stronger fizz when hot hydrochloric acid is used.

Marble is a limestone or a dolostone that has been metamorphosed. It will have an acid reaction that is like the limestone or dolostone from which it was formed.

Some sedimentary rocks are bound together with calcite or dolomite cement. **Sandstone, siltstone, and conglomerate** sometimes have calcite cement that will produce a vigorous fizz with cold hydrochloric acid.

Calcite and other carbonate minerals have a low resistance to weathering and can be attacked by acids in natural waters and soils. When testing material that has been exposed at Earth's surface, it is very important to test unweathered material. A fresh surface can usually be obtained by breaking the rock.

Some rocks are porous and contain a reservoir of air. Small amounts of air escaping into a drop of acid from below can give the appearance of a gentle acid reaction because a few bubbles will emerge out of pore spaces. To avoid this problem you can scratch the rock across a streak plate and test the powder or the grains that are produced [21].

3. Research Methods and Materials

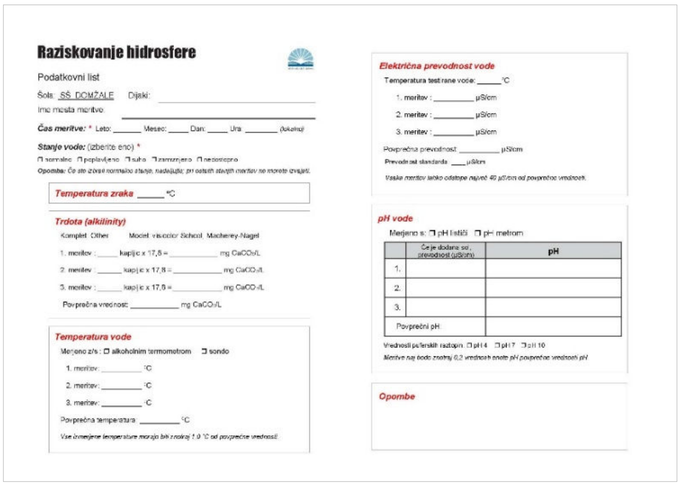
3.1 Hydrosphere Study Site

Name	Most za stadionom *(Student Group RiverScout03)*				
Latitude	46.135807°	Longitude	14.602626°	Elevation	294.4m

Atmosphere Site	Obstacles	bridge
	Buildings	none
	Thermometer Type	other: soil or air
Hydrology Site	Water Body Name	Kamniška Bistrica
	Water Body Type	fresh_water
	Water Body Source	river
	Bank to Bank Distance	22.0 m
	Water Sample Location	bank
	Can See Bottom	Yes
	Bank Material	Soil
	Bedrock Type	Limestone
	Freshwater Habitat	has Rocky Substrate , has Mud Substrate , has Logs

Table 2. Site Information

Figure 19. *Photographs of our Hydrosphere Study Site*



Raziskovanje hidrosfere

Podatkovni list

Šola: SŠ DOMŽALE Dijaki: ______

Ime mesta meritve: ______

Čas meritve: * Leto: ____ Mesec: ____ Dan: ____ Ura: ____ *(lokalno)*

Stanje vode: (izberite eno) *

Temperatura zraka ____ °C

Trdota (alkilinity)

Komplet: Other Model: visocolor School, Macherey-Nagel

1. meritev : ____ kapljic x 17,8 = ____ mg CaCO₃/L
2. meritev : ____ kapljic x 17,8 = ____ mg CaCO₃/L
3. meritev : ____ kapljic x 17,8 = ____ mg CaCO₃/L

Povprečna vrednost: ____ mg CaCO₃/L

Temperatura vode

Merjeno z/s : ☐ alkoholnim termometrom ☐ sondo

1. meritev: ____ °C
2. meritev: ____ °C
3. meritev: ____ °C

Povprečna temperatura: ____ °C

Električna prevodnost vode

Temperatura testirane vode: ____ °C

1. meritev : ____ µS/cm
2. meritev : ____ µS/cm
3. meritev : ____ µS/cm

Povprečna prevodnost: ____ µS/cm

Prevodnost standarda ____ µS/cm

pH vode

Merjeno s: ☐ pH lističi ☐ pH metrom

	Če je dodana sol, prevodnost (µS/cm)	pH
1.		
2.		
3.		
Povprečni pH		

Vrednosti pufrskih raztopin: ☐ pH 4 ☐ pH 7 ☐ pH 10

Opombe

Figure 20. *Hydrosphere Investigation Data Sheet*

Figure 21. *The Equipment for Field Work*

3.2 Air Temperature

We used the *Current Air Temperature Protocol. (The Protocol in full >>)*

Figure 22. *The Air Temperature Measurement*

We measured the air temperature by holding the thermometer at chest height, in the shade, and away from our body for three minutes, recording the temperature reading in our science log and then holding the thermometer the same way for another minute. Afterwards, we recorded the temperature once again. If the temperature was within 0.5 °C of the previous reading, we recorded the reading on our *Data Sheet*. If the two temperature readings differed by more than 0.5 °C, we repeated the measurement.

If two consecutive temperature readings weren't not within 0.5 °C of one another after 7 minutes, we recorded the last measurement on the *Data Sheet* and reported our other four measurements in the comments section along with a note that our reading wasn't stable after 7 minutes.

3.3 Water Temperature

We used the *Water Temperature Protocol for Thermometer Probes*. (The Protocol in full >>)

Figure 23. *The Water Temperature Measurement*

We put the thermometer probe into the sample water to a depth of 10 cm and left it in the water for 3 minutes. We read the temperature without removing the probe from the water and let the probe stay in the water sample for 1 more minute. We read the temperature again and if the temperature had not changed, we recorded the temperature on the *Data Sheet*. If the temperature hadn't changed since the last reading, we repeated the measurement until the temperature stayed the same.

We repeat the measurement with two new water samples and calculated the average of the three measurements. All temperatures should be within 1.0 °C of the average. If they were not, we repeated the measurement.

After the measurement we rinsed the probe with distilled water and blotted it dry.

3.4 Water Alkalinity/Total Hardness

We used the *VISOCOLOR®* School reagent case, test kit for performing titrimetric tests on total hardness.

Figure 24. *The Total Hardness Measurement*

We poured 5 mL of the water sample into the sample jar using the plastic syringe, added 2 drops of GH-1 and shook the jar to mix the contents. The water sample turned red. *If the water sample turns green, this means that there are no hardness-producing substances.*

Holding the dropping bottle GH-2 vertically we added GH-2 drop by drop, shaking the specimen at the same time to mix until it turned green.

We counted the number of drops. One drop corresponds to one degree of total water hardness – 1 drop ≙ 1.3 °e ≙ 17.8 mg/L $CaCO_3$.

After use, we immediately sealed the dropping bottles and thoroughly rinsed out the sample jar [18].

3.5 Electrical Conductivity

We used the *Electrical Conductivity Protocol*. (The Protocol in full >>)

Figure 25. *The Electrical Conductivity Measurement*

The water sample temperature should be between 20-30 °C, before we measure its electrical conductivity. Our water sample temperature was always below 20 °C, so we filled a clean sample bottle with the water to be tested and brought it back to the school laboratory. We waited until the water temperature reached at least the lower limit, recorded the temperature, and then measured the electrical conductivity.

We rinsed two 100 mL beakers two times with sample water and poured about 50 mL of water to be tested into the beakers.

We rinsed the probe with distilled water and blotted it dry, then put the probe in the water sample in the first beaker and stired gently for a few seconds. The meter mustn't rest on the bottom of the beaker or touch the sides. Then we took the probe out of the first beaker, shook it gently to remove excess water and then put it into the second beaker without rinsing with distilled water. We left the probes submerged for at least one minute. When the numbers stopped changing, we recorded the value on the *Data Sheet*.

We repeated the measurement twice using fresh beakers of water each time and calculated the average of three observations. Each of the observations should be within 40 µS/cm of the average. If one or more of the values was not within 40 µS/cm, we repeated the measurements with fresh water sample and calculated a new average.

We rinsed the probe with distilled water, blotted it dry, and put the cap on the meter.

3.6 Water pH

We used the *pH Meter (Electrical Conductivity Greater than 200 mS/cm) Protocol*. (The Protocol in full >>)

Figure 26. *The Water pH Measurement*

First, we calibrated our pH meter according to the manufacturer's directions.

Then we put the electrode part of the meter into the water and stirred once with meter. The meter mustn't touch the bottom or sides of the beaker. We waited for 1 minute and if the pH meter was still changing numbers, we waited another minute and then recorded the pH value on the *Data Sheet*.

We repeated the measurement twice using new water samples and recorded pH values on *Data Sheet*. All three observations should be within 0.2 of average; if they were not, we repeated the measurements.

We rinsed the electrode with distilled water and bloted it dry, turned off the meter and put on the cap to protect the electrode.

3.7 Carbonate Rocks Test – The Acid Test

Figure 27. *Part of the river nearby our school*

For the test of carbonate rocks, or the acid test, we used a 10% solution of hydrochloric acid, which was dripped onto the selected stones. We observed whether bubbles of carbon dioxide appeared and the strength of foaming. If necessary, we rubbed the surface of the stone so that the acid contacted the stone surface better.

Figure 28. *The Acid Test*

4. Results and Discussion

Nº	Measured At		Current Air Temperature (°C)	Water Temperature (°C)	Hardness (mg/L $CaCO_3$)	Conductivity (µS/cm)	pH
	Date	Time (Local)					
1	2023-11-16	12:50	10.2	8.0	178	293	8.1
2	2023-11-22	11:55	10.8	8.2	160	332	8.2
3	2023-11-29	12:50	5.7	7.1	166	347	7.9
4	2023-12-06	13.01	4.6	7.0	125	285	7.9
5	2023-12-13	11:50	flooded	flooded	flooded	flooded	flooded
6	2023-12-20	13:05	3.1	6.1	154	322	7.9
7	2024-01-03	12:52	8.5	7.9	148	334	7.6
8	2024-01-10	12:55	2.7	4.8	137	326	7.9
9	2024-01-17	13:00	1.8	5.3	148	347	8.1
10	2024-01-24	12:03	0.1	4.6	142	330	8.0
11	2024-01-31	12:55	5.1	4.6	160	355	7.9
12	2024-02-14	12:55	9.2	7.1	148	341	8.3

Table 3. Air and Water Temperature, Water Hardness, Conductivity, and pH for the period between November 16, 2023, and February 14, 2024

4.1 Air and Water Temperature

Temperature is an important variable because it affects many physical, chemical, and biological processes in water and affects the values of measurements of other quantities.

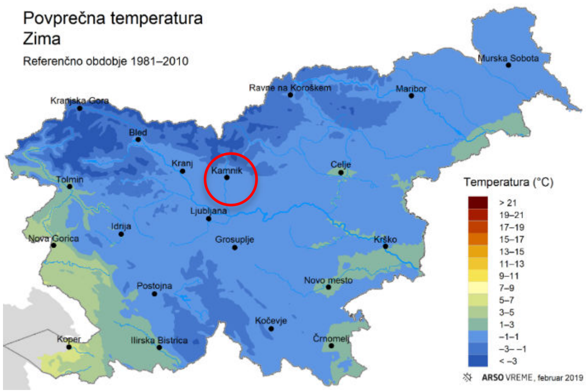


Figure 29. *Winter average air temperature (1981/82-2009/10)*

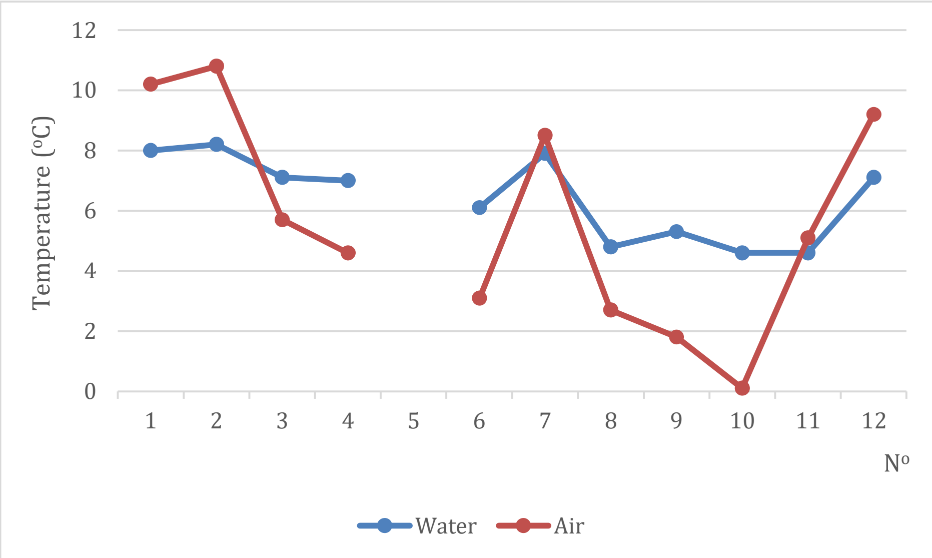
Since the measurements were taken in winter, the air and water temperatures were expectedly low (Table 3), although not exactly typical for winter, according to winter average air temperature from 1981 to 2010 [22].

This gave us the **idea** that it would be reasonable and important to observe changes in the climate over a longer period to find out how they affect life in and along the river and consequently our lives.

When we compared the temperature of the air and the temperature of the water during the measurement period, we found that as the temperature of the air changes, the temperature of the water also changes. As the temperature of the air decreased, the temperature of the water also decreased, and as the temperature of the air increased, the temperature of the water also increased. However, we noticed that the changes in water temperature were not as large as the changes of air temperature, which can be explained by the different specific heat of air and water:

c(water) = 4200 Jkg^{-1}K^{-1}, c(air) = 1000 Jkg^{-1}K^{-1}.

Specific heat tells us how much heat (energy) in Joule we need to bring 1 kg of substance to heat it by 1 K. To heat 1 kg of water by 1 K, we need 4200 J of heat; if 1 kg of water is cooled by 1 K, it releases 4200 J of heat [23]. The water has an unusually high specific heat, which is the reason that the sea or lake warms up for a long time in spring and cools down slowly in autumn and early winter, which has a favorable effect on the sea climate. We think, that in the case of a fast-flowing river, such as the Kamniška Bistrica, this property of water is not so obvious [24].



Graph 1: Correlation of current air and water temperature for the period between November 16, 2023, and February 14, 2024

4.2 Total Hardness

Our measurement results (Table 3) show that the water in the river is medium hard [25], but according to the limits for hardness from other sources [26], we can estimate that it is hard. We can say that we have confirmed the first hypothesis that the water in the Kamniška Bistrica River is hard.

From this we conclude that there is a considerable amount of mineral substances dissolved in the river water, which can affect both electrical conductivity and pH.

We expected higher values of total hardness, but if we consider that Kamniška Bistrica is fast flowing river and that there were rain and snow precipitation on the measurement day or few days before or after it (Table 4), we conclude that the river may not have time to dissolve the rocks to a greater extent and the rain or snow could lower the total hardness of the water.

We could check our conclusion by observing the river for longer periods of time and in other seasons (like summer) when its water level may be lower.

DOMŽALE lon=14.6022, lat=46.1343, viš=296m	rain	snow
2023-11-14	yes	no
2023-11-15	no	no
2023-11-16 (M)	yes	no
2023-11-17	no	no
2023-11-18	no	no
2023-11-19	no	no
2023-11-20	no	no
2023-11-21	yes	no
2023-11-22 (M)	no	no
2023-11-23	no	no
2023-11-24	yes	no
2023-11-25	no	no
2023-11-26	no	no
2023-11-27	yes	no
2023-11-28	yes	no
2023-11-29 (M)	no	no
2023-11-30	yes	yes
2023-12-01	yes	no
2023-12-02	yes	yes
2023-12-03	no	no
2023-12-04	no	yes
2023-12-05	yes	no
2023-12-06 (M)	no	no
2023-12-07	no	no
2023-12-08	no	yes
2023-12-09	yes	yes
2023-12-10	yes	no
2023-12-11	yes	no
2023-12-12	no	no
2023-12-13 (M)	yes	no
2023-12-14	yes	no
2023-12-15	no	no
2023-12-16	no	no
2023-12-17	no	no
2023-12-18	no	no
2023-12-19	no	no
2023-12-20 (M)	yes	no

DOMŽALE lon=14.6022, lat=46.1343, viš=296m	rain	snow
2023-12-21	yes	no
2023-12-22	yes	no
2023-12-23 - 2023-12-28	no	no
2023-12-29	no	no
2023-12-30	no	no
2023-12-31	yes	no
2024-01-01	yes	no
2024-01-02	yes	no
2024-01-03 (M)	yes	no
2024-01-04	no	no
2024-01-05	yes	no
2024-01-06	yes	no
2024-01-07	yes	no
2024-01-08	no	yes
2024-01-09	no	no
2024-01-10 (M)	no	no
2024-01-11	no	no
2024-01-12	no	no
2024-01-13	no	no
2024-01-14	no	no
2024-01-15	yes	no
2024-01-16	no	no
2024-01-17 (M)	yes	no
2024-01-18	yes	no
2024-01-19	yes	yes
2024-01-20	no	no
2024-01-21	no	no
2024-01-22	no	no
2024-01-23	no	no
2024-01-24 (M)	no	no
2024-01-25	yes	no
2024-01-26	no	no
2024-01-27	no	no
2024-01-28	no	no
2024-01-29	no	no
2024-01-30	no	no
2024-01-31 (M)	no	no

[27]

Table 4. Precipitation in Domžale for the period between November 14, 2023, and January 31, 2024

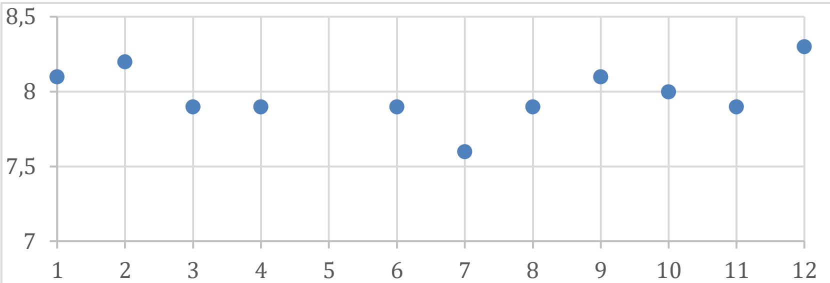
4.3 Electrical Conductivity

Electrical conductivity for distilled water is 0.5 to 3 µS/cm [28], for drinking water 50 to 300 µS/cm and for surface water 100 to 10,000 µS/cm [29]. Mid-range conductivity 200 to 1000 µS/cm is the normal background for most major rivers [30]. Our measurement results (Table 3) are in the lower part of mid-range conductivity, so they indicate that the water has a normal rather than excessive concentration of ions that can contribute to electrical conductivity. We confirmed the second hypothesis, the electrical conductivity of river water is much higher than the electrical conductivity of distilled water.

Conductivity outside this range or significantly elevated electrical conductivity could indicate that pollution has entered the river. We didn't notice large deviations in the measurement results.

We started thinking, how can human activity change electrical conductivity or temporarily elevate it? Any human activity that adds charged chemicals to a river will alter the electrical conductivity (chloride and phosphate from household products, winter road runoff, containing salt …).

4.4 pH



Graph 2: pH for the period between November 16, 2023, and February 14, 2024

The lowest measured pH value was 7.6, and the highest was 8.3 (Table 3). We confirmed the third hypothesis – the pH of the water is basic but was changing a little during the measurement period.

Since we were interested in why there are differences, one of the assumptions was a higher amount of precipitation on the day of the measurement or a few days before. When we investigated the weather during the measurement period, it appeared that the lower pH values coincided with the period of precipitation on the same day or the days before (Table 4). When we measured the lowest value (January 3, 2014), it rained for four days in a row, including the day of the measurement.

Given that we found that rocks in the river are predominantly carbonates and that the electrical conductivity values indicate a greater presence of dissolved ions in the water and that the river water is medium hard/hard, we can conclude that the river water is slightly alkaline because of the presence of ions that entered the water through the dissolution of carbonate rocks.

Our next task would be to check the buffering capacity of the river water and the connection or impact of this capacity on the flora and fauna that live in the river and indirectly also on the people who live in the vicinity of the river or use it for recreation.

4.5 Carbonate Rocks Test – The Acid Test

Figure 30. *The Acid Test Results*

We collected various stone samples on the riverbanks and on river sediments. Unfortunately, we could not reach the rocks at the bottom of the river, due to the greater depth of the river or its fast current. The samples were tested with a solution of hydrochloric acid.

A strong reaction and strong gas bubbling was observed in most samples, but in some reactions were less obvious. We also found stones that did not give a reaction to the acid test, but they were in a small minority.

We confirmed the fourth hypothesis, that rock samples from riverbanks and alluvium will contain carbonate rocks.

Based on the information in the literature and the results of the acid test, we conclude that there are carbonate rocks in and along the river, which the river water and acid rain can dissolve and thus contribute to the presence of dissolved mineral substances in the water.

5. Conclusion

Figure 31. *Kamniška Bistrica*

Kamniška Bistrica is an economically and environmentally very important river, which has a great influence on its surroundings, natural or urbanized. It enabled people to exist and develop in this area, and they adapted it to their needs. A serious problem is pollution, which began with the development of the surrounding industry, but is now much more under control thanks to sewage treatment plants and environmental laws.

The river is located near our school, so the decision to explore it was logical and easy. Since many people use it for walks and other types of recreation, we thought it's important to start researching its characteristics and observe whether they might be changing, so that in case of deterioration, we could warn of negative changes and take timely action.

We started with simple measurements such as temperature and pH, then, based on the obtained results and the questions that arose, we expanded the research by measuring electrical conductivity and hardness.

Through our research work, both experimental and theoretical, we learned that:

- The air and water temperatures are related, but changes in water temperature are smaller than changes in air temperature, which can be explained by its higher specific heat compared to air.
- The water in Kamniška Bistrica River is hard, which means that a lot of mineral substances are dissolved in it; the high hardness of the water may cause that river water is not directly suitable for use in heating systems, because of excretion of limescale can complicate the operation of these devices.
- The electrical conductivity of river water is much higher than the electrical conductivity of distilled water, so the concentration of ions that can contribute to electrical conductivity is high, which is probably also a result of the high hardness of the water.
- The water pH is slightly basic, due to the dissolved carbonate rocks (which we found on the bank and alluvium and tested with the acid test) and is connected to the alkalinity of the water.

Going forward, we plan to research and find answers to the following questions:

- Does the pH level remain constant throughout the year or varies seasonally?
- Are there specific locations along the river where the pH is consistently higher or lower?
- How does pH and carbonate hardness act as a buffer in water systems?
- How does the pH-carbonate system function as a buffer against external changes in pH?
- How do variations in pH and carbonate hardness impact aquatic life, including fish and other organisms?
- What are the sources and factors (natural or anthropogenic) influencing pH and carbonate hardness in the river? How do these factors impact the overall water quality and aquatic ecosystem health?

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Figure 1. The Earth System: https://www.globe.gov/ (February 4, 2024)

Figure 2. The Water Cycle: https://gpm.nasa.gov/education/water-cycle (February 4, 2024)

Figure3. The River Spring (Personal Archive, July 18, 2017)

Figure 4. Kamniška Bistrica Valley, upper end: Avtor: Borut Kantuser – lastno delo; licenca: CC BY-SA 3.0; URL: https://commons.wikimedia.org/w/index.php?curid=17943212 (February 21, 2024)

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Figure 8. GLOBE Data entry Logo: https://www.globe.gov/globe-data/data-entry (February 4, 2024)

Figure 9. Thermometer: https://market.mikro-polo.si/files/shop/c30195/P_21/2/il-060.01.001.jpg (February 21, 2024)

Figure 10. Water Temperature (Personal Archive, May 18, 2023)

Figure 11. Electrical Conductivity (Personal Archive, March 1, 2023)

Figure 12. pH (Personal Archive, February 28, 2023)

Figure 13. pH Scale: SMRDU, Andrej; SNOV IN SPREMEMBE 2, Učbenik za kemijo v 2. letniku gimnazije, III. izdaja po učnem načrtu iz leta 2008; Založništvo Jutro (February 4, 2024)

Figure 14. Carbonate System Ions and Molecules: https://salinity.oceansciences.org/highlights03.htm (February 18, 2024)

Figure 15. Total Hardness (Personal Archive, February 17, 2024)

Figure 16. Limescale: https://en.wikipedia.org/wiki/Limescale#/media/File:Limescale-in-pipe.jpg (February 18, 2024)

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Figure 27. Part of the river nearby our school (Personal Archive, February 1, 2024)

Figure 28. The Acid Test (Personal Archive, February 1, 2024)

Figure 29. Winter average air temperature (1981/82-2009/10): https://meteo.arso.gov.si/uploads/probase/www/climate/image/sl/by_variable/temperature/leto_in_sezone/temp_zima_8100.png (February 20, 2024)

Figure 30. The Acid Test Results (Personal Archive, February 1, 2024)

Figure 31. Kamniška Bistrica (Personal Archive, May 12, 2022)