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Spectrophotometric detection of molecular indicators as an alternative geoengineering tool for water source quality management

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Abstract
Earth's hydrological cycle, consisting of the atmosphere, plant cover, unsaturated zone and groundwater, allows the continual exchange of substances and energy through physical, chemical and biological processes. Weather extremes (floods, droughts, tornadoes) and the effect of global warming reflected in the ocean level and the increased occurrence of forest fires lead to the study of local relationships to introduce adaptation measures specifically to water sources and biodiversity management. The selected territory focused on specific model objects requires deep knowledge of its geographical and geophysical characteristics, including (micro)climatic conditions. The precise origin of (micro)climate change or its consequences, such as chemical parameter variations or water amount fluctuations, have not been fully described. Geo-engineered proposals for potential Earth temperature management are on theoretical recommendations. Therefore, this terrain physicochemical work describes interactions between water source parameters and locally specified meteorological conditions (water depth, water temperature, wind speed, air temperature and air moisture). The monitoring of the model dug well entitled Studnička pod Senderovom (village Vinné, Michalovce district, Košice region, Eastern Slovak Lowland) has run within 2022 – 2023 seasons. Spectrophotometric qualitative and quantitative analysis in the visible and ultraviolet electromagnetic spectrum of wavelengths allowed chemical parameters: iron, sulphates, phosphates, nitrates, and calcium analysis. Measurable and regular monitoring of chemical and meteorological components can be an effective tool for the implementation of direct measures to protect biodiversity, agriculture, and economics. In addition, suggested research can contribute to predicting potential life self-organization in various water sources that are important in hydrological, cosmic, and planetary sciences.

Keywords
Water, geoengineering, iron, nitrates, nutrients, spectrophotometry.

Introduction

Quality of life and technological progress are closely associated with the Earth's state. Climate change and temperature fluctuations disturb all fields of life, including the availability of resources and the global economy. Climate-driven (temperature growth) and anthropogenic environmental (urbanization and increasing demand for natural resources) factors affect rising ocean tiers, soil droughts, unexpected floods or salt intrusion in river deltas (Atwood et al., 2023; Novák, 2022; Eslami et al., 2021). Heating Antarctica's ice and the surrounding Southern Ocean causes a significant impact on ecosystem processes (Convey & Peck, 2019). In addition, climate change could lead to varied responses in forest ecosystem composition and biodiversity changes by phylogenetic-specific groups or their total loss (Fei et al., 2017; Lambers, 2015). Complications in precipitation predictability, changes in precipitation amounts, and their seasonal variability highlight this problem (Le et al., 2023). Researchers and political elites are still seeking efficient tools to prevent damage to natural resources, animal and plant species, food, health and economics caused by the greenhouse effect in the background of rapid technological progress and population growth on the other side. The iron hypothesis based on carbon dioxide (CO_2) uptake in Fe-rich water (Martin, 1990) can be a suitable geo-engineered proposal for potential Earth temperature management.

Iron content in water sources related to meteorological conditions fluctuations could contribute to the novel approach to the life origin interpretation. Such theories predict inorganic CO_2 as the primary source of organic matter and biological objects' genesis. In the work of Varma et al., 2018, the reduction of CO_2 to the Acetyl-Coenzyme A (the key molecule in energetic metabolism in cells, i.e. Krebs cycle) was suggested using native transition metals Fe^0, Ni^0 and Co^0 at the temperature ranges between 30 and 100°C. Temperature, pressure and reaction time effect on iron-promoted CO_2 fixation in aqueous solution simulated possible pathways under conditions mild enough for a proto-metabolism (Varma et al., 2018). Reductionist physical or chemical experimental research (in the levels of molecules or energy) requires a new key to understanding the ground of living systems organization (Chirumbolo & Vella, 2021). In addition, water as the essential life environment was understood only as a neutral medium or background for various solutes.

In addition, water as the essential life environment was understood only as a neutral medium or background for various solutes. Curious phenomena such as the "memory of water" (Elia et al., 2007), singularities in water waves (Fontelos & De La Hoz, 2010), the role of water in physiological ageing (Hahr, 2019), water genesis on Earth or potential occurrence on other space objects highlight the water importance. Moreover, water provides an excellent medium for iron kinetics and reaction description. Redox iron ion reactions followed by hydroxyl anions capture, rapid precipitations of various Fe/O/H compounds, hydrolysis, nucleation and crystallization affected by pH changes or thermal transformation are examples of how iron can adapt to rapidly changing conditions. This adaptation, typical for one of the life manifestations in the aerobic system, cannot be replaced by another metal element. For these reasons, iron belongs to essential trace elements for living cells.

Iron, created within the star's thermo-nuclear fusion, occurs in Earth (Earth's core, water, soil, minerals) and almost all living forms (bacteria, plants, animals, including humans) in Fe^0, Fe^{2+}, Fe^{3+} oxidation states in complexes Fe^{4+} and Fe^{6+}. Iron, a biogenic element, participates in many metabolic events (respiration - oxygen transport; DNA - deoxyribonucleic acid, RNA - ribonucleic acid and many protein syntheses). The most significant property of iron is redox potential in the defined physicochemical composition of the surrounding medium, allowing iron to cycle in the environment (Taylor & Konhauser, 2011). For planetary sciences, analysis of the iron state enables the investigation of banded iron formations in the early stages of Earth (Mitchell et al., 2021). The ability of iron to lose electrons could be used to destroy pollutants (Guan et al., 2019). In oceans, Fe-oxidation could be spontaneous through ultraviolet photooxidation, reaction with oxygen, anaerobic photosynthesis or bacteria and lower organisms, especially from sediments and minerals sources (Bekker et al., 2010). Released energy from the common Fe^{2+} ions oxidation has a high advantage for living cells, i.e. energy gain for their biochemical processes. The bioavailability of iron is related to its oxidation state and redox potential, depending on the temperature, pH, and presence of oxidants/reductants in the aqueous medium. For example, the visible effect - solubility of the most abundant Fe^{2+} and Fe^{3+} ions in water pH distinguishes these ions. While Fe^{2+} hydrated ions are relatively soluble in the whole pH range, Fe^{3+} is insoluble until it achieves a pH below 3 (Ilbert & Bonnefoy, 2013).

Young Earth's ocean a billion years ago contained ferrous ions (Williams, 2012). Probably just after oxygen influence, the number of ferric ions increased, and evolution-pressured organisms had to adapt to elude Fe^{3+} phase property thanks to biomineralization (Ilbert & Bonnefoy, 2013). Magnetotactic bacteria can bind iron in Fe_3O_4-monocrystals surrounded by a lipid membrane and arrange magnetosome chains (Chang & Kirschvink, 1989). Other bacteria, higher organisms, and humans are equipped with ferritin protein, which stores iron as FeOOH-like nanocrystals. The storage ferritin function ensures iron for DNA replication and growth needs. Iron, a co-factor of many enzymes, accelerates reactions during cell reproduction, proliferation and growth. Ferritin protects cells from the toxic effects of iron excess, which could initiate oxidative stress (Ilbert & Bonnefoy, 2013). Organisms from the animal kingdom search for iron nutrients by movement to find them in the environment and food resources. However, Fe-sensing in plants is not a fully clarified mechanism, which appears to integrate environmental signals: light, temperature (e.g. climate change) and other nutrients (Kobayashi et al., 2019; Tsai & Schmidt, 2017). Plants'

Fe-reduction strategies are regulated biochemically and genetically when Fe^{2+} deficiency with the aim of Fe^{3+} bioavailability increases (Graziano & Lamattina, 2005). While Fe-S clusters are part of enzymes in respiration, chlorophyll biosynthesis, photosynthesis, regulation and gene expressions, ferritin protects a plant's DNA against oxidation damage, especially in iron excess in the environment (Kobayashi et al., 2019). Iron usability in the soil-water-atmosphere-plant cover system depends on biotic, abiotic and meteorological factors at Earth connected by complicated interaction processes. The iron amount and its redox cycle significance assessment concerning the greenhouse effect require other measurable nutrients for plant cell reproduction and growth, such as nitrates, sulphates, phosphates and calcium determination. Different climate scenarios could affect the rate of nitrates (NO^3) transport in the soil, which is not proven yet (Stuart et al., 2011).

Usually, nitrate-based fertilizer applications enhance crop growth. The disadvantage is leaching to the lower layers of soils or subsurface waters during over-fertilization. Sulphates (SO_4^{2-}), necessary for proteins, carboxylic acids and fats biosynthesis or vitamins (thiamine, biotin) formation, can increase nitrogen usage. Phosphates (PO_4^3) are essential for DNA, RNA, and ATP. Without these components, phosphorylation, glycolysis and photosynthesis could not run. Calcium (Ca^{2+}) plays a significant function in biological membranes and the colloidal state of the cytoplasm stabilization and participates in phosphorylation, nitrate reduction, carotene synthesis, and assimilation of molecular nitrogen and osmotic processes in the cell. Optimal pH regulation between 6-7, saturated sorption complex formation for soil, cell growth and development, and protein production are examples of many important Ca^{2+} roles. Without local field data, it will not be possible to understand biodiversity deprivation or transition as a spontaneous response to the mentioned climate change. Weakly explained fluctuations in wells water level, limited to numerical modelling (Wada et al., 2010), and changes in nutrient transport rate mentioned by Stuart and co-authors (2011) support the importance of the current monitoring study.

Selected parameters of the model that were well in terrain conditions were measured and analyzed in this work. Iron, sulphates, phosphates, nitrates, calcium concentration, water level, water and air temperature were monitored at the stone-lined forest well (Fig. 1A), entitled "Studnička pod Senderovom" (Fig. 1B).

A. *B.*

Fig. 1. Photo of A: the forest well entitled B: "The well below the Sender" (Studnička pod Senderovom)

The model well, suitable for the present study, is localized in the middle of the Laborec River basin drainage network and southwest of Vihorlatské vrchy, Eastern Slovakia Lowland (Fig. 2A). A location map of the drainage network, which belongs to the Laborec River basin, was precisely described and illustrated elsewhere (Vojtko et al., 2012; Zeleňáková et al., 2021; Kubiak-Wójcicka et al., 2021). The Laborec drainage basin as a segment of the Carpathians is composed of tectonic units of the External Carpathians, relics of the Neogene molasse deposits, Central Carpathian Palaeogene deposits, Pieniny Klippen Belt, and Neogene volcanics. The study area, characterized by an asymmetric stream network pattern, belongs to the province of the Eastern Carpathians and the subprovince of the External Eastern Carpathians. The most extensive part of the Laborec River basin drainage network belongs to the Laborecká vrchovina Mountains. The Vihorlatské vrchy Mountains line the southern part of the study area, and the eastern flank extends to the Bukovské vrchy Mountains (Vojtko et al., 2012). The well-known location is visible by a massive wooden cross, where the medieval church remains and stone architectural elements (11^{th} – 13^{th} century) are present (Fig. 2B). This territory is used mainly for historical-archaeological research. The dug well was built in the nature reserve Vinianska stráň – Senderov with an area of 282 400 m^2 used for research, educational and cultural-educational goals since 1984. Climatically, the territory belongs to a warm or moderately warm region and a slightly humid subarea. This work aims to better understand interaction processes by analyzing field-collected data from 2022 to 2023. Graphical illustrations of time trends could help predict future scenarios based on a well-studied model in natural conditions.

A.

B.

Fig. 2. The scheme of A: studied locality in the Eastern Slovakia Lowland marked red, and B: photo of the "Romanesque church of the Holy Cross" (Románsky kostolík svätého Kríža), taken on January 2023

Materials and methods

The samples collection and in situ terrain measurements.

The forest well water level was measured using tape on specific dates. Water temperature affects physicochemical and biological events in water sources, especially reaction kinetics, chemical transformation, or transport processes. The standard mercury lab thermometer allowed air and sample temperature measurements. Because pH affects redox reactions and the bioavailability of various ions for different living cells, pH values were obtained in collected samples. GPS has allowed the necessary meteorological and geographic state concerning object/locality extraction.

Spectrophotometric quantitative analysis of chemical parameters of aqueous samples.

Absorbance directly proportional to the concentration of measurable parameters following Lamber-Beers Law (Eq. 1) was measured using pHotoFlex pH and standardized reagent mixtures (WTW, measurement and analysis technology s.r.o., Banská Bystrica, Slovakia). Lambert-Beer's law expression describes the optical attenuation of a physical material of uniform concentration in a defined optical path length through the sample (absorptivity):

$$A = log(I_0/I) = \varepsilon(\lambda) * c * d \quad (1)$$

where A is the absorbance, I_0 is the beginning light intensity, I is detected light intensity after sample absorption or attenuated light intensity, ε is the molar extinction coefficient (absorptivity) of the attenuating species at specific λ_{MAX} [M/cm], λ is the wavelength of the electromagnetic radiation [nm], c is the concentration of the attenuating species [M], and d is the optical path length; usually 1 cm measuring cuvette.

The LED light source with an optical filter allowed absorbance measurement for visible light wavelengths: 436, 517, 557, 594, 610 and 690 nm. Each method for a searching parameter represented a pre-set programme, nitrates – program no. 314 and phosphates no. 306. Nitrate's presence visualization by colour change has run after the reaction with sulfuric acid and chromophore reagent solution. Application of the sample into the Ø 16 mm glass cuvette allowed to determine NO_3^- within the mass concentration range of 1 - 133 mg/L. Phosphates (PO_4^{3-}) mass concentration from the 0.02 - 2.45 mg/L range after reaction with powder reagent containing dipotassium disulphate was measured into the Ø 28 mm glass cuvette. Standardized methods with powder and liquid reagents were used for quantitative analysis of iron, sulphates, and calcium using a spectrophotometer Hach Lange DR6000. The high-speed scanning in the wavelength range between 190 – 890 nm allowed lambda max vertical or horizontal shift detection as a response to changing external conditions. Pre-set programme no 270 allowed the calculation of iron concentration in the 0.012 – 1.800 mg/L range in collected aqueous samples.

The powder reagent contained a mixture of sodium disulphide, sodium thiosulfate and sodium thiosulfate after application to the aqueous sample, allowing violet visualization of Fe presence at wavelength 590 nm. Automatic program no. LCK 327 allowed the determination of calcium (Ca^{2+}) concentration in the range of 5 - 100 mg/L at 572 nm. Reagents consisted of powder and liquid organic and inorganic substances. The result of citric acid and barium chloride-containing powder reagent with dissolved sulphate (SO_4^{2-}) is white turbidity detectable using pre-set programme 680 in the concentration range 2 - 70 mg/L at wavelength 450 nm.

Results and discussion

The model well is placed 257 meters height above sea level with a diameter of 80 cm, depth of 85 cm and geographic coordinates 48°48'13.302" N 021°59'6.828" E (Google Maps Digital Address Plus Code: RX3P+F3H Vinné). Tab. 1 shows water depth, water temperature, wind speed, air temperature and moisture.

Table 1. Meteorological conditions and physical parameters

The number of the well state control	Date	Water depth [cm]	Water content [L]	Water temperature [°C]	Air temperature [°C]	Wind [km/h]	Air moisture [%]
1.	14th March 2022	residual	–	–	12	11 (JJV)	21
2.	28th April 2022	residual	–	9.6	16	11 (S)	52
3.	16th June 2022	residual	–	–	27	11 (JJV)	35
4.	4th September 2022	dry	–	–	23	7 (JJV)	48
5.	15th September 2022	12	60	23	25	15 (JZ)	58
6.	23rd January 2023	76	382	10	6	31 (SSZ)	100
7.	23rd March 2023	52	261	10	18	11(J)	52
8.	16th July 2023	20	100	16	32	15 (JV)	46

The subsurface water level (content) is necessary for its transfer to the root zone of the soil profile for the forest vegetation supply. In the case of decreased subsurface water levels, the soil and vegetation start to dry (Maurel & Narcy, 2020). The driest periods from the table were from March to September 2022. The autumn and winter months have led to water supply regeneration. A decrease in water content was observed again in July 2023. The air temperature time trend, with red marked points related to the water samples collection, is graphically illustrated in Fig. 3. The linear regression has shown a slightly increasing air temperature during the monitored season 2022-2023, and the coefficient of determination $R^2 < 1.0$ points on almost negligible dependence. The air temperature minima were observed during January – March and maximum in May – September. The lowest temperature point -2°C- was detected on 12th January 2022 and 5th February 2023, and the highest was on 16th July 2023.

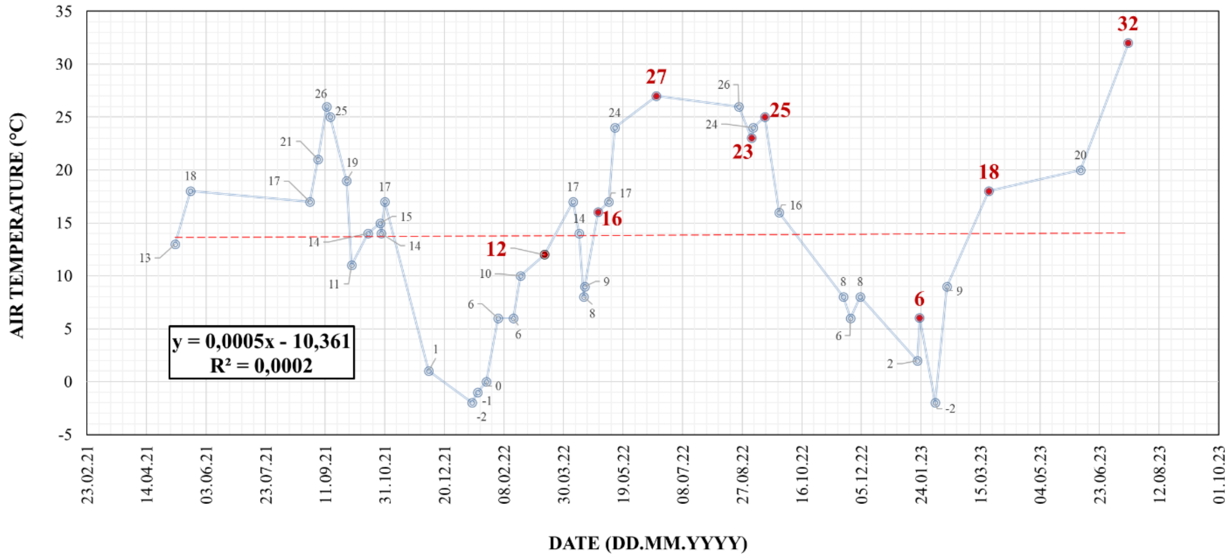
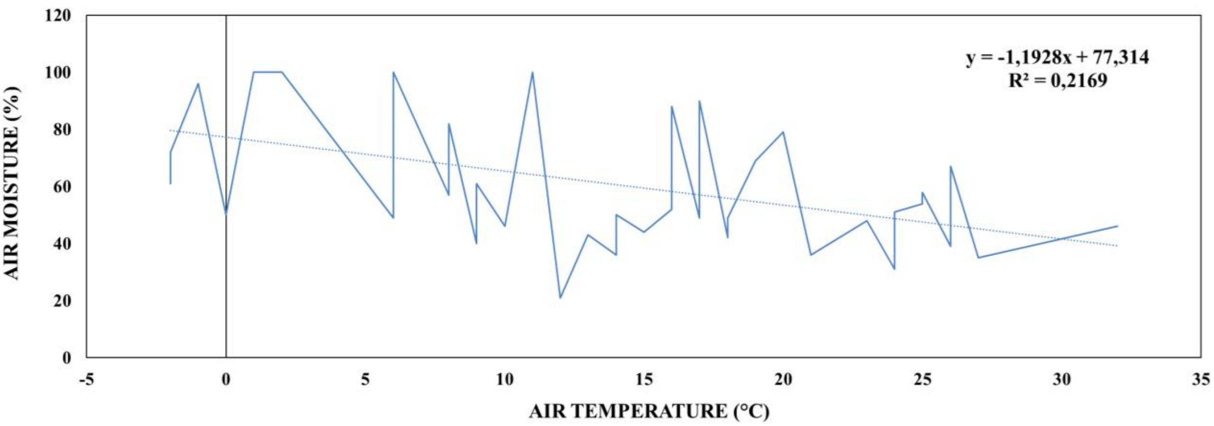


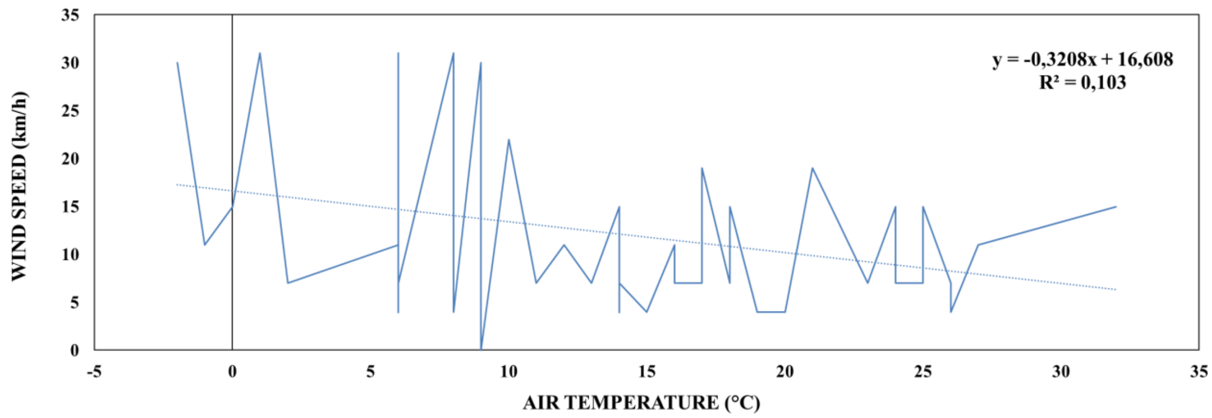
Fig. 3. Graphical visualization of monitored air temperature trend in natural conditions from 14th March 2022 to 16th July 2023. Water collection was realized during red-marked dates

The combination of obtained interacted meteorological parameters, illustrated in Fig. 4A, 4B, and 4C, showed a decreasing dependent relationship of R^2 0,2169 > 0,103 > 0,00004.

A.



B.



C.

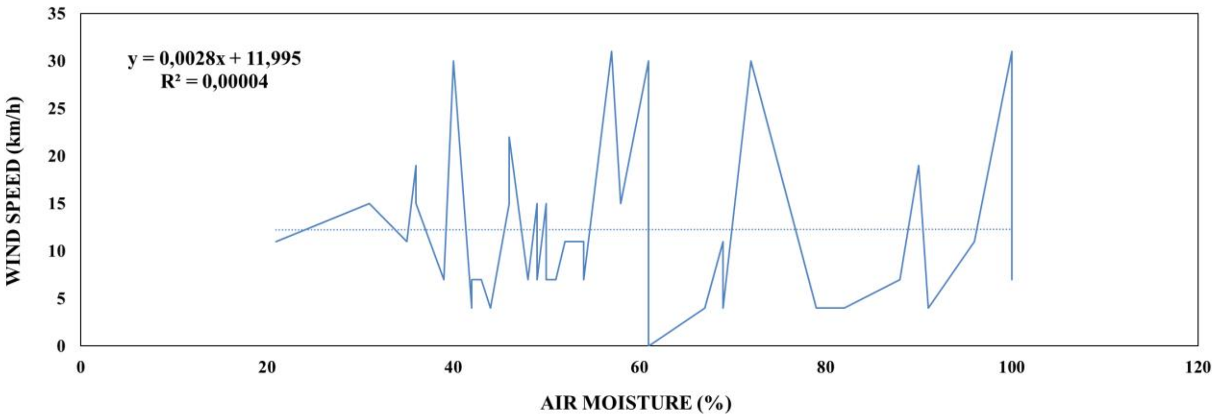


Fig. 4. *Meteorological parameters according to the determination coefficient R^2 decreasing A: air moisture versus air temperature, B: wind speed versus air temperature, and C: wind speed versus air moisture*

The linear regression calculation showed the highest dependence on air moisture and temperature interaction. When air temperature grew, air moisture decreased (Fig. 4A). Wind speed affected air temperature about half less (Fig. 4B), and air moisture was almost unaffected by wind speed (Fig. 4C). The Earth's hydrological cycle allows air mass organization and vapour condensation to get water again to a liquid state into Earth's surface. For this reason, wind speed should not cause water evaporation from Earth planet. On the other hand, it causes horizontal air mass circulation along Earth's atmosphere. Spectrophotometry with appropriate chemical assays allowed rapid determination of nitrates, iron, sulphates, calcium and phosphates concentration, with results collected in Tab. 2.

Table 2. Results summarization obtained by quantitative spectrophotometric analyses

The number of collected aqueous samples	$c_{(NO3)-}$[mg/L]	c_{Fe} [mg/L]	$c_{(SO4)2-}$ [mg/L]	c_{Ca} [mg/L]	$c_{(PO4)3-}$ [mg/L]
1	33	0,066	40	9,17	0,540
2	35	0,056	45	9,68	0,600
3	28	0,040	50	9,55	0,830
4	-	-	-	-	-
5	27	0,140	52	9,21	0,312
6	65	0,080	36	9,05	0,590
7	59	0,074	39	9,26	0,510
8	48	0,103	43	9,98	1,050

According to EU legislation (2020/2184), iron concentration in drinking water for human consumption should not exceed 0.2 mg/L, nitrates 50 mg/L, phosphates 1 mg/L, sulphates 250 mg/L compared to Tab. 2, only nitrate concentration slightly increased in January and March 2023. Phosphate concentration exceeded in July 2023. Calcium in water (for diet or health maintenance) should be more than 30 mg/L. Data in Tab. 2 showed a very soft character of well water at each collection date point. Nevertheless, the samples were not acid pH values and did not exceed the range of 6–7.

The qualitative analysis by scanning aqueous samples at 190 – 890 nm wavelength range showed the λ_{MAX} at 280 nm. After background (blank/reference) subtraction of pure deionized water, observed λ_{280} peaks (Fig. 5) could signify the presence of protein or nucleic acid (DNA/RNA). The absorbance of proteins visible at 280 nm can be visible thanks to the phenol group of tyrosine amino acid and the indole group of tryptophan amino acid. Natural examples of these groups' presence are various plant, animal or human extracts (almonds, avocados, bananas, seeds, alkaloids from plants, mushrooms: *Psilocybe*; serotonin, melatonin, nicotinamide).

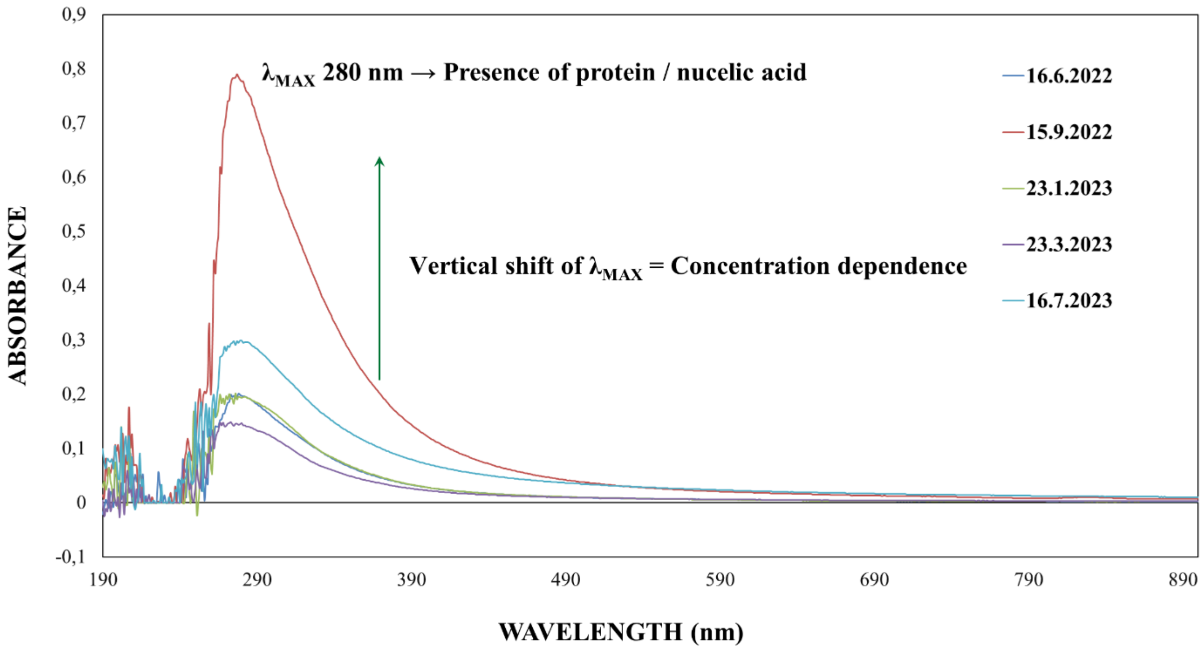


Fig. 5. Wavelength scan for the quality control of aqueous samples.

Because of calibration absence using the one known specified bio-macromolecular component (BC) standard, λ_{280} peak shifts were analyzed in the next step (Fig. 5). The dependence of A ~ c in Lambert-Beer expression allowed BC % amount ratios calculation, changing during the season (Fig. 6), while the 100 % of BC concentration assigned for the highest absorbance (the highest peak) allowed comparisons with other samples.

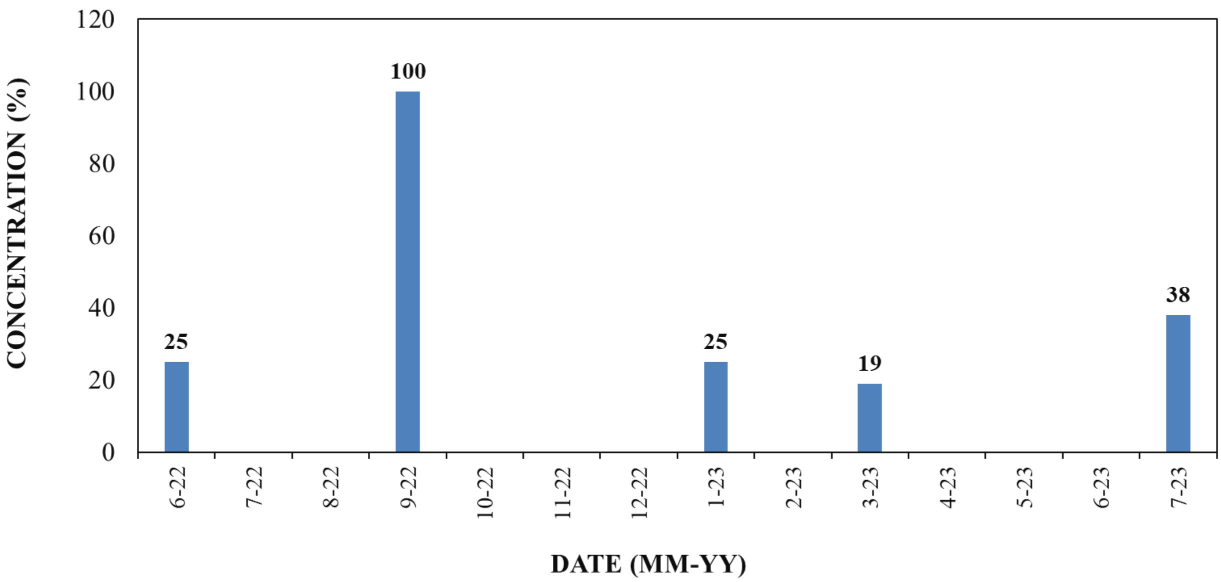


Fig. 6. Comparison of concentration ratios of BC in aqueous samples during seasons.

Hydrochemistry requires the quantification of chemical parameters' effect on the water quality. Determined substances allowed the assessment of their influence on the BC incidence or formation. R^2 - coefficients calculated from linear regression equations, arranged according to the most dependent parameter, revealed iron in the first place (Tab. 3).

Iron and sulphates with BC growth could suggest pre-dominance of Fe-S cluster formation as part of enzymes in many metabolic pathways (respiration/ chlorophyll/ biosynthesis/ photosynthesis/ regulation and gene expressions in plants). Decreasing amounts of nitrates, phosphates and calcium could signify the lack of these components for BC assembly in the studied forest dug well. Therefore, lower organisms (for instance, cyanobacteria) in this water have limited resources for reproduction and growth. Additional measurements (for instance, mass spectrophotometry, X-ray diffraction, and fluorescence methods) are necessary for water or Fe-S clusters (Hanikel et al., 2021), BC (proteins/enzymes) types and their size characterization. Living species (bacteria, insects or small animals) and their abundance require microscopic methods. This study could help to define the probability of the future occurrence of specific organisms according to the content of chemical parameters, especially in stagnant waters (stagnant wells, swamps, reservoirs, lakes).

Table 3. Linear regression analyses of chemical parameters in relation to BC amount/air temperature

Relation	with BC amount		with air temperature		with water temperature	
Parameter	R^2	Linear regression equation (y)	R^2	Linear regression equation (y)	R^2	Linear regression equation (y)
Iron	0,7259	+0,0009x + 0,0484	0,0278	+0,0006x + 0,0741	0.9907	+0.0048x + 0.0283
Sulphates	0,4467	+0,1376x + 38,305	0,4788	+0,4738x + 33,765	0.9617	+1.1024x + 26.240
Nitrates	0,3734	–0,3183x + 58,579	0,4754	–1,1950x + 71,211	0.9745	–2.6688x + 89.115
Phosphates	0,2706	–0,0045x + 0,8430	0,2203	+0,0134x + 0,3693	0.0533	–0.0117x + 0.7876
Calcium	0,0186	–0,0015x + 9,4718	0,6801	+0,0300x + 8,7618	0.0375	+0.0129x + 9.1841

According to Table 3, nitrates were the main limiting factor for the creation and higher organization of BC or living cells. Chemical parameter amount variations related to air local temperature linear regression analyses showed calcium as the most dependent parameter on air temperature. Results showed iron can affect BC creation with the lowest iron response to air temperature. It could mean that with an unchanged amount of iron in a closed system, the electron transfer necessary for oxidation-reduction reactions, catalysis, or enzyme kinetics/activity is much more pronounced, and the influence of photons transfer from an external source (from the Sun) is negligible in this case. The linear correlation (R^2) of iron, sulphates and nitrates was most visible as water temperature dependence with the decreased trend of nitrates amount with water temperature growth caused probably by evaporation of N-gasses. Phosphates and calcium were weakly affected by water temperature.

Iron properties, such as solubility, oxidation state, and chemical formula, play a significant role in climate regulation. While soluble iron will catalyze plant metabolisms and growth, magnetite nanoparticles getting by anthropogenic combustion into the atmosphere could be climate forcer with a heating effect through the absorption of solar radiation (Matsui et al., 2018).

Carbon dioxide, predicted as one of the main contributors to the greenhouse effect after exceeding its concentration in the atmosphere (Manabe, 2019), mainly from sources of fossil fuels and volcanic eruptions, is naturally released during the respiration of plants (in the dark) but also physiologically in animals and humans. Based on this current terrain/laboratory work showing iron as the highest chemical influencer in water, some questions are still arising:

Could iron play a crucial role in CO_2 fixation during the formation of higher plants in water?

Could it be possible that the management of iron distribution or iron fertilization can change (micro)climate temperature?

The presented study represents the pilot results, focused on the chemical parameters leached into the forest well determination. Because the iron content in this shallow water source varies during seasons and depends on precipitation and forest growth especially, the defined iron amounts needed for the microclimate change assessment can be relevant after the territory monitoring for the next several decades. Similar local research can significantly contribute to clarifying questions followed by a broader view of these complex problems. In any case, the water areas building containing aquatic plants with strongly regulated amounts of chemical nutrients can contribute to favourable forests, parks, and urban microclimatic conditions. The recent assessment supports similar adaptations proposed concerning land use changes that can be more significant than the influence of carbon dioxide emissions on the atmosphere (Novák, 2023).

Conclusion

The main goal of the work was to study interactions between water source parameters and locally specified meteorological conditions. Spectrophotometric qualitative and quantitative analysis in visible and ultraviolet electromagnetic spectrum allowed chemical parameters characterization. Data collection and analysis of similar water sources in natural conditions could help predict parameters important for living cells' development. With knowledge of measurable environmental local component combinations for water management directed to biodiversity, agriculture protection can be an effective tool for regional economic protection. In addition, monitoring chemical components could help predict the probability of life self-organization, which is important in hydrological, cosmic, and planetary sciences. Without local field data, it will not be possible to understand biodiversity deprivation or transition as a spontaneous response to global climate change. The suggested geo-engineered proposal for potential Earth temperature management highlights the importance of similar physicochemical terrain and laboratory studies.

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