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Evaluating of the environmental risks of natural water sources in the Alkalaa municipal community area – South Lebanon

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ABSTRACT

Water is considered a fundamental factor, and plays a role in public health and economic growth. Therefore, it should be free of all kinds of microorganisms, and chemical substances that are dangerous to fauna and flora. Insufficient water supply is one of the issues confronting Middle Eastern countries, and Lebanon becomes a typical example. This study aims to evaluate the basic physical, chemical, and microbiological water properties for eight distinct sites, in southeastern Lebanon, identified during the coronavirus pandemic, as the worst economic situation to hit Lebanon began. These tests were carried out by the World Health Organization (WHO). The results were utilized to assess the level of environmental pollution. A comparison was made between the obtained results with other studies: Lebanon southwest and the northwest region of Jordan Valley. The novelty of this study stems from the fact that it is the first to shed light on the degree of pollution level and the lack of environmental education for water conservation and water pollution prevention in this unstudied area, and compares the results locally and regionally. In addition, the obtained results indicate the impact of the Coronavirus on the behavior of the habitants in this region.

Key words: coronavirus pandemic, environmental education, Lebanon, Northwest of Jordan, physiochemical and microbiological characterization, water conservation

HIGHLIGHTS

- Check the importance of habitat education in saving water and reducing its pollution to prevent losses at different levels (human life and economic way).
- Encourage the researches to take into consideration such catastrophic situations and ensure water purification worldwide.
- Study the effect of Coronavirus on the behavior of people in the same country and in the same region during the Corona pandemic.

GRAPHICAL ABSTRACT

INTRODUCTION

The blue planet, the third planet in the solar system, is covered by 71% water. The latter is a unique natural source, in the sense that it can be renewed but not replaced. The majority of this water is salty and therefore cannot be consumed (97%). About 3% of the water present on the earth is freshwater, only part of which is available for various human uses, most of which is locked up in the polar glacier caps. Resources for water are not distributed consistently worldwide and are often limited in arid and semi-arid regions such as the Middle East. More than 40% of the world's population faces some form of water scarcity (WHO 2022). There are many substitutes for the various sources of energy and for the majority of raw materials, but there is no substitute for water. It is an essential resource for all living beings on the earth. It has different uses, from the most basic, such as consumption or agriculture, to the most advanced, such as the chemical industry. Water that can be consumed without the risk of harm in the short or long term is a fundamental element of human life.

It is clear that the effect of population growth and the water requirements is gradually increasing. The decrease in the amount of water available becomes more and more serious due to the reduction and lowering of the amount of precipitation on the one hand, in parallel with climate change that disrupts the water cycle, and water pollution on the other hand (Postel *et al.* 1996). Water permanently receives pollutants of different types such as organic matter, in addition to industrial and domestic discharges, which affect directly the water quality and reduce its availability. When the water becomes enriched with dangerous substances (ions, heavy metals, and bacteria), its normal characteristics will be altered (Daou *et al.* 2018). Such water becomes synonymous with health disasters, as well as environmental and aesthetic problems. Therefore, the treatment of polluted water has become an urgent need to continue normal human life. The past few years have seen a significant amount of research conducted regarding the numerous types of anthropogenic pollution that affect groundwater quality, seas, and oceans (Nguyen *et al.* 2022; Mousavi *et al.* 2023a, 2023b).

Lebanon, with a land size of 10,452 km^2 and a coastline stretching 210 km from north to south, is located on the Mediterranean Sea's eastern shore. However, it is like a water tower in a region plagued by aridity. This country receives a large volume of precipitation which is found in surface waters and groundwater. But this country could run out of water in the coming decade due to drought. Indeed, out of a total of 9.6 billion m^3 of annual precipitation, only 1.3 billion is used. Furthermore, the rest either evaporates, pours into the Mediterranean Sea, or reaches other countries (Blanc 2006).

Moreover, Lebanon has 40 rivers, including 17 perennials and 23 seasonal. The quantity of surface and underground water is around 2.6 billion m^3, while two billion are actually exploitable. The annual rainfall volume over Lebanon is almost 8,600 million mm^3. This precipitation feeds the water sources in Lebanon, which are concentrated in six months of the year (from November to April) while the rest of the year is dry throughout the territory. Most of this water is lost by evaporation (almost 50% of the total volume of precipitation) while another significant proportion is lost via the flow of surface water to neighboring countries (Kassem *et al.* 2020).

Lebanon is filled with faults of all sizes. The Yammouneh Fault, which extends along the western edge of the Bekaa and connects the major Jordan Valley fault to the Ghab Valley Fault in Northern Syria, is Lebanon's longest fault. The Lebanese part of the Dead Sea Transform Fault is a lateral, or strike-slip, fault. Nearly all rocks in Lebanon are sedimentary, with the majority of them being pale limestones. Despite the immense thicknesses of limestone, the range of limestone types is very limited with a fine-grained majority (Nader 2014).

Basaltic flows and intrusions of various ages are the sole igneous rocks. Only a few metamorphic rocks are found in thin areas along the intrusions' borders. Regional supply (Litani River, degradation of Eocene and Cretaceous rocks in the Tyre vicinity, and reprocessing of brown/black sediments on the Tyrian shoreline) and local input (adobe infrastructure destruction, cultural inputs) have all had a role in the infilling of Tyre's ancient harbor (Mariner *et al.* 2011).

Water quality in Lebanon is a problem. Groundwater suffers from the infiltration of pollutants, which can be, for example, wastewater, industrial waste, decomposing solid waste, etc. Population growth, proliferation uncontrolled drilling well, and lack of sanitation in populated areas are among the problems facing freshwater. As a result, surface waters and rivers are in danger due to pollutants coming mainly from human activities (Nassif 2019).

This study will focus on water from natural springs and more specifically groundwater where the objective is to determine the quality for drinking and irrigation of these springs which are located in the region of the municipal union Alkalaa in southeastern Lebanon. The characterization of the water quality for these sources in certain cities will be discussed referring to the obtained results of physical, chemical, and microbiological analyses. The parameters presented in this study were tested and evaluated in the laboratory. In addition, a lockdown emergency related to the Corona pandemic was encountered (during laboratory tests), which limited proceeding with more experimental studies. The worst economic situation that faced our country, Lebanon, was an additional factor in eliminating additional tests that were previously planned.

Recently, several districts and cities of the Alkalaa community have been faced with a major disruption in the drinking water supply, due to fairly large population growth. To meet the needs of the population and solve this lack of water, collected water in an artesian well and various natural sources, which have been there for decades, have been used. Two studies were achieved in the Alkalaa community, east of Lebanon, within five villages that overlook Jabal Amel Valley (2019 and 2022) to study the water's physiochemical quality and microbiological pollution levels.

In 2019, during the Corona pandemic that hit the entire planet, some researchers (Tarawneh *et al.* 2020) studied the water physiochemical quality in the Northwest of Jordan (Jordan Valley). Jordan's Hashemite Kingdom has an area of around 96,500 km^2 in the Arabian Peninsula's northern corner. The majority of the post-Paleozoic rocks are neritic and bathyal sedimentary rocks from the weak shelf in northwestern, northern, and possibly northeastern Jordan. The total depth of sedimentary strata above the Precambrian bedrock in northeastern Jordan may be upwards of 7,000 m. In the studied region, litho units/unconsolidated sediments varied in age from Upper Cretaceous to Recent and include modern soils; Quaternary alluvial fans, calcrete, and marl; Tertiary conglomerate, limestone, chalk, and cherty limestone; and Cretaceous limestone and dolomite (Moumani *et al.* 2011).

Jordan's population is 11.15 million people. Precipitation falls during the short, chilly winters, with yearly totals ranging from 16 inches (400 mm) in the northwest along the Jordan River to no more than 4 inches (100 mm) in the south of the country. Three significant rivers exist in Jordan: the Jordan River and both of its significant branches, the Yarmuk and Zarqa Rivers, which join it in the north (Shammout *et al.* 2023). Overlap with other works, within the same region, is normal due to the rapid spread of environmental pollution, which is accelerating and worsening due to non-compliance with laws and lack of supervision. Furthermore, other researchers evaluated the water physiochemical quality and microbiological analysis of Ras El-Ain natural ponds in Lebanon Southwest within a worse economic situation (Khatib *et al.* 2023a, 2023b). Based on these studies, quarterly and not even annual monitoring and measurements of all kinds of pollution (more precisely surface and groundwater pollution) is needed.

The aim of this study is to achieve three levels of comparisons: firstly between the collected data of the Alkalaa community in 2019 and 2022. A regional comparison will be disserted the obtained results between Jabal Amel Valley (eight locations) in Lebanon, which is located within the latitudes (33° 06′ and 33° 15′) and Jordan Valley (six locations) located within the latitudes (32° 21′ and 32° 30′). Both valleys samples were located within 09′ as a latitude interval, and have a common latitude (35° 34′). Finally, an evaluation will be assessed between the results of Lebanon Southeast and Southwest in 2022 within the same two longitudes (33° 06′ and 33° 15′) as shown in Figure 1.

The studied areas had different dramatic changes in both topography and weather conditions. The community of municipalities Alkalaa (12 villages) rises above the sea between 550 and 750 m. It does not exceed 20 km^2, located in the Jabal Amel Valley between five villages with 27 km as an average distance from the Mediterranean coast. The maximum recorded temperature varied between 7 °C (winter at night) and 32 °C (summer at noon), while Ras El-Ain ponds (Southwest of Lebanon) is a coastal one (around 1 km from the Mediterranean coast), with a rainy climate in winter, and drought in summer, and had almost the same interval of temperature. However, the Jordan Valley is located 70 km from the Dead Sea, and elevated at 1,337 m above the sea. It has an arid to semi-arid climate with scorching summers and mild winters. During the summer, the highest temperature reaches 40 °C and drops to around 10 °C at night during the winter. The total inhabitants in the five villages (Tibnine 17%, Safad El Batikh 6%, Soultaniyeh 5%, Aita El Jabal 6%, and Haris 16%) of the Alkalaa municipalities are around 43,000 inhabitants (50%) of the Bint-Jbeil district's population (Figure 2).

Water from the Ras El-Ain natural ponds has recently been transported to adjacent cities and villages, irrigating more than 30 km^2 of agricultural land, which has more than 300,000 inhabitants. However, the Jordan Valley's inhabitants were estimated to be 197,000 inhabitants. Due to the lack of water quantity and the reduced amount of precipitation, the inhabitants of the studied cities are obligated to buy water to fulfill their needs. These three locations are suffering from a large migration of refugees without having their exact numbers due to a lack of data and their non-official continuous movement.

Different sources remained almost dry or dried up early, which is not the case for Ain El Mezrab and Ain El Warde sources in Tibnine city, in addition to the Ain El Hamam, and Ain El Bakar sources in Safad El Batikh city. The Ain El Warde and Ain El Mezrab springs are springs flowing from the 'Siddiq' mountain in the city of Tibnine, as well as the Ain El Hamam springs, its filter, and Ain El Bakar, which depend on water flowing from the mountain of Safad El Batikh village and adjacent mountains, whose water accumulates in an underground reservoir. Today, these springs are the refuge of most of the inhabitants of the Bent Jbeil region.

In Aita El Jabal village, towards the south side, there are natural and permanent water sources such as Ain El Tayta and Ain El Jawze. There are also temporary springs that will only appear during the rainy season. The sources of Ain El Tayta and Ain El Jawze are located in the valley separating the villages of Aita El Jabal and Beit Yahoun. The artesian well has been built

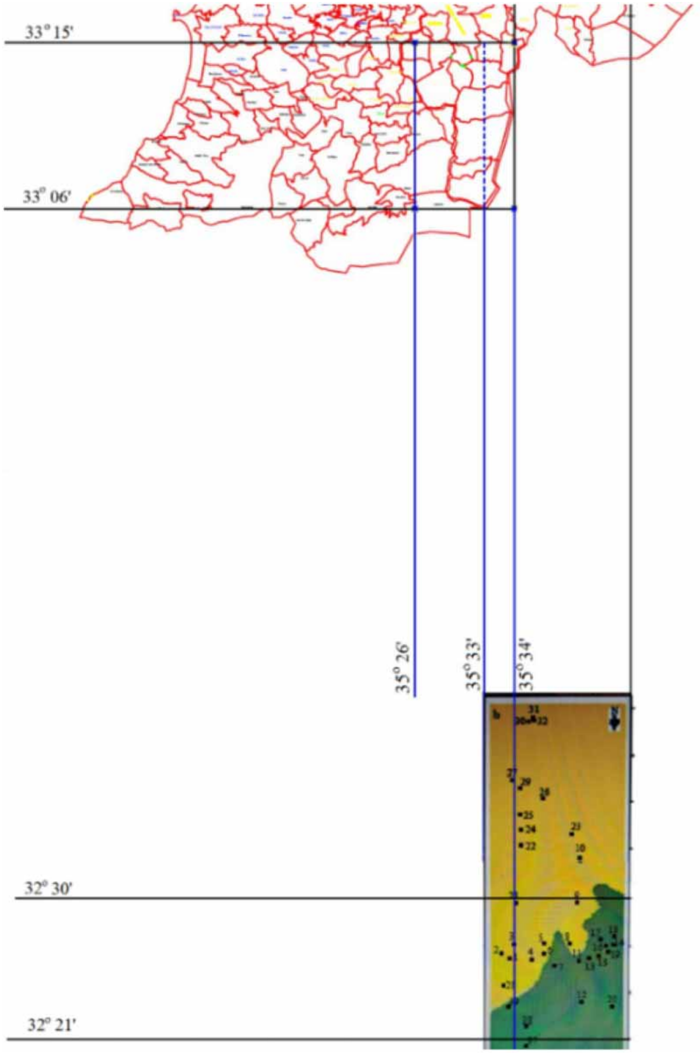

Figure 1 | Sites locations.

since 1989, in addition to the existence of a plastic greenhouse 500 m far away. The water from this well was used for domestic and agricultural purposes.

METHODS

Water samples were chosen from eight different resources in the Alkalaa region. For each site, almost 800 mL of raw water was taken and put in plastic bottles and tightly closed. These water samples were stored in coolers during transport and still cooled until the testing days. All the tests were achieved within a few days to quantify their pollution degrees by carrying out both physicochemical and microbiological characteristics. The site elevations and the types of activities around the springs studied in the region are presented in Table 1.

Additional precaution was taken into consideration concerning the samples intended for microbiological analysis, they were reserved in sterile containers. The microbiology tests were achieved firstly to avoid any bacterial multiplication and then the physicochemical parameters. In addition, an air space had left of at least 2.5 cm in the plastic bottles, which facilitates the homogenization of the sample at the analysis time in the laboratory. All the selected locations are shown on a 3D map using the geographic information system (GIS) system (Figure 3). The microbiological analyses were carried out at the laboratory of the Faculty of Agronomy, Dekwaneh. The microbiological analysis of the samples requires the preparation of suitable culture media.

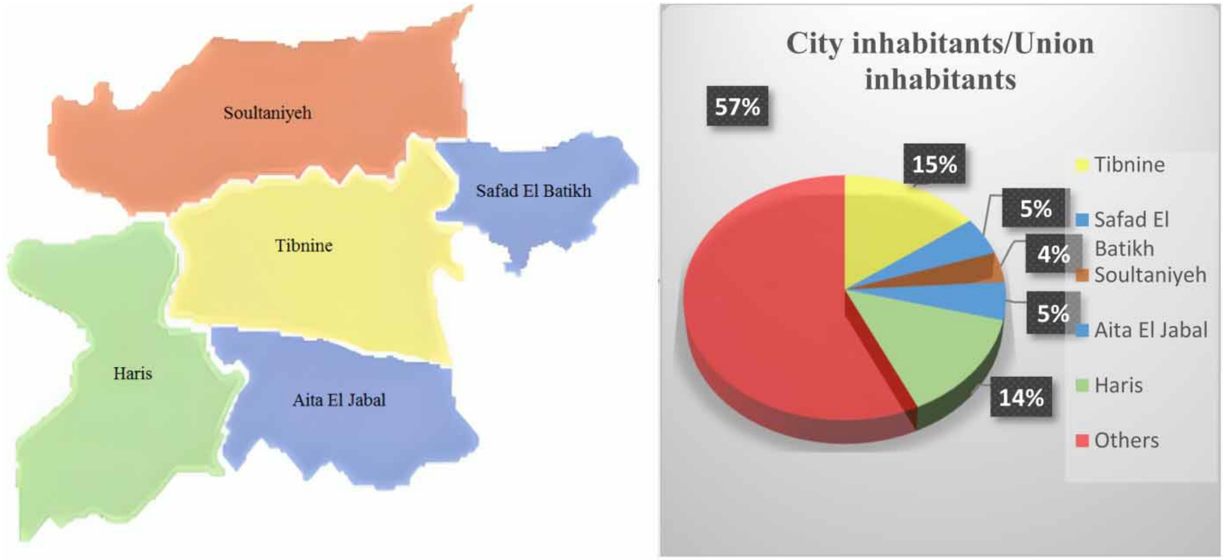

Figure 2 | Population distribution map for the selected cities.

Table 1 | Site locations and types of activities

Sites		Latitudes (North)	Longitudes (East)	Altitudes (m)	Types of activities/uses
S1	Ain El Mezrab	33° 12′ 10″	35° 25′ 26″	526	Irrigation, domestic, and drinking water
S2	Ain El Hamam	33° 12′ 02″	35° 25′ 42″	555	
S3	Hamam filter	33° 12′ 02″	35° 25′ 42″	555	
S4	Ain El Warde	33° 12′ 11″	35° 25′ 20″	535	
S5	Ain El Bakar	33° 12′ 06″	35° 25′ 43″	560	Irrigation and domestic
S6	Ain El Tayta	33° 10′ 26″	35° 24′ 40″	593	
S7	Ain El Jawze	33° 10′ 05″	35° 24′ 22″	615	
S8	Artisian Well	33° 10′ 47″	35° 23′ 59″	603	

In this study, three types of bacteria were studied: total coliforms (TCs), *Escherichia coli* (*E. coli*), and *Salmonella*. In each case, a specific culture medium was prepared.

By using a graduated pipette, 1 mL was taken from the tested water, then it was distributed on the entire surface of the culture medium using a sterile spreader. The solutions (water + culture medium) were left next to the flame (so that the medium remains sterile) until they gelled. The reading was made after 48 h of incubation in Macconkey agar as a culture medium at 37 and 45 °C after 24 and 48 h, respectively (for TCs and *E. coli*). However, the culture medium for *Salmonella* bacteria was Shigella agar at 37 °C after 24 h. The bacteria, on the surface, give rise to colonies isolated from each other which can be directly counted. It is assumed that each colony corresponds to a bacteria.

The water's physical properties were measured using different apparatus. The pH (potential of hydrogen) meter is a parameter that indicates the degree of acidity of the water. The 'Pocket Tester' was used to evaluate both the electrical conductivity (EC) and the total dissolved solids (TDS). TDS reflects the mostly dissolved inorganic compounds in water, while EC is an excellent indicator of the mineralization of water (Mohammad *et al.* 2018).

The analyzed anions were F^-, Cl^-, SO_4^{2-}, NO_2^-, PO_4^{2-}, and Br^-. The analysis of anions (fluoride, sulfates, nitrites, and bromide) was made at the Doctoral School of Science and Technology (DSST) at the Lebanese University, and their concentrations were measured by the method of ion chromatography (IC). The principle of this method (Figure 4) is based on the properties of ion exchange resins, which allow selective fixation of the anions or cations presented in the

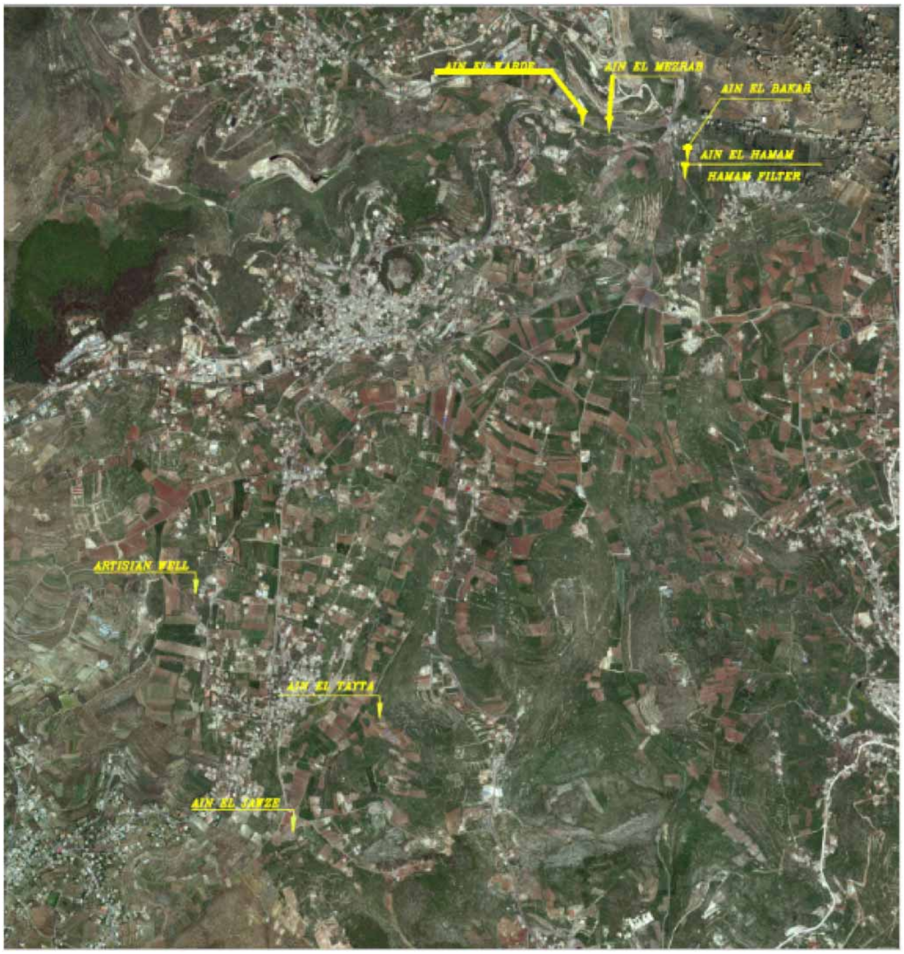

Figure 3 | GIS studied locations.

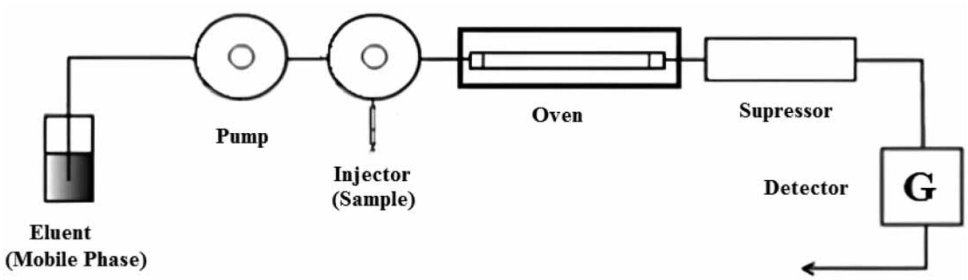

Figure 4 | IC chromatography process.

solution. On the resin packaged, in the form of a chromatography column, an eluent constantly circulates. The analyzed solution is injected and the ions are fixed selectively on the column. Then, the ions are released according to their size, their charge, and their degree of hydration. Each ionic species is separated and detected at the outlet of the column (Haddad 2004).

Chloride (Cl^-) and phosphate (PO_4^{2-}) ions were analyzed at the Dekweneh University of Agronomy. The concentrations of chloride anions were measured by the titrimetric method. This method is one of the analytical methods based on the determination of a reagent of known concentration which is required to react completely with a volume solution containing the analyte. However, the concentration of phosphates was obtained using the spectrophotometer. It measures the absorbance of a solution at a given wavelength. In practice, the device measures the intensity of light after it has passed through a tank containing the solution to be studied. The intensity of the emitted monochromatic light (I_0) is known. From the intensity of the transmitted light (I), the device gives the absorbance (A) as follows: $A = \log(I_0/I)$ (Figure 5) (L'vov 2005).

The concentrations of positive ions (cations) were evaluated by using flame atomic absorption spectroscopy at the DSST. The checked cations are the following elements Ca^{2+}, Fe^{2+}, Mg^{2+}, and Pb^{2+}.

RESULTS AND DISCUSSION

The experimental study was carried out on eight water locations taken from the municipal community Alkalaa, in particular from the villages Tibnine, Safad El Batikh, Aita El Jabal, and Haris, to determine the physicochemical and bacteriological parameters of eight natural water sources. For the two years, 2019 and 2022, all the samples were taken on 30 April. The latter is for microbiological analysis, where the samples are analyzed the following day. As mentioned before, the obtained results are processed and discussed in three categories in table forms: the first one within the same area in the Alkalaa municipality (2019 and 2022), then between the east and west of Lebanon (locally 2022), and between the two valleys: Jabal Amel and Jordan (2019). To facilitate the comparison an average value will be taken for all the obtained results.

Physical analysis

This research will enable the interrelationship and assessment of the reservoir's numerous naturogenic and anthropogenic elements. The average pH levels in the Alkalaa villages were 7.15 in 2019 and 7.1 in 2022. The average pH for Ras El-Ain natural ponds is equal to 6.9 and for the Jordan Valley 7.6. All these values were within the allowed range between 6.5 and 8.5 (WHO 2022).

The dissolved solids are mostly composed of chlorides, sulfates, bicarbonates, calcium, magnesium, and sodium. These solids come from natural sources, municipal and industrial effluents, runoff from agricultural land, and the fallout of atmospheric particulate matter. The most significant impact of TDS on the quality of water is flavor modification.

A very high or very low concentration of TDS limits growth and can cause the death of several aquatic organisms. The Alkalla villages had 320 mg/l as TDS average value in 2019 and 286 mg/l in 2022 (10.63% decreased). This reduction is referred to the establishment of filters before the water intake. Furthermore, the average TDS for Ras El-Ain natural ponds was 339 mg/l and for the Jordan Valley 337.3 mg/l. The obtained values exceeded the WHO standard for drinking water for all the samples, except that for Alkalaa villages in 2022 (300 mg/l). However, the water is suitable for irrigation since the TDS results were less than 500 mg/l (WHO 2022).

Water having an EC of more than 1,000 s/cm norm for drinking water (WHO 2022) is highly mineralized and unsafe for human consumption. The FAO recommended that EC values should be less than 3,000 s/cm standards for irrigation water (FAO 2022). The high conductivity alters the availability of free metals to plants and wildlife. Pipes can be corroded by water with a concentration of less than 180 s/cm (Konan *et al.* 2018).

The average EC values for the chosen sites in the Alkalaa municipalities were 583 μs/cm in 2019 and 483 μs/cm in 2022 (17.15% decrease). This improvement is due to the replacement of certain deteriorated water pipelines in the municipality before the examination sites. However, the average EC for Ras El-Ain natural ponds was 661 μs/cm and for the Jordan Valley 1,467.5 μs/cm. All these values do not exceed the international recommendations for drinking or irrigation (500–1,000 μs/cm). However, it surpassed the WHO recommendations for drinking in the Jordan Valley (WHO 2022).

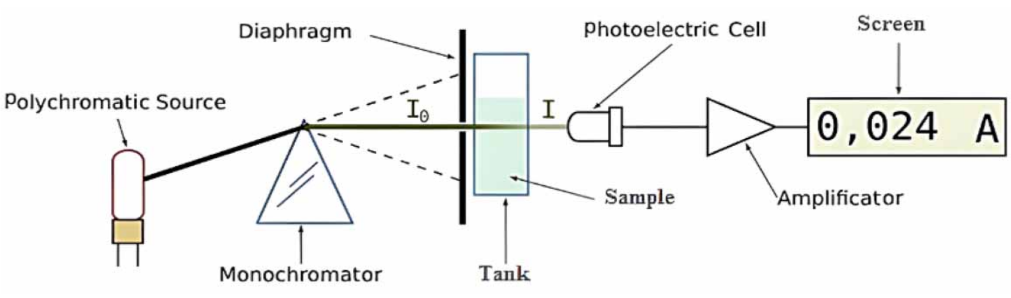

Figure 5 | Spectrophotometer process.

Chemical analysis

Chlorides are abundant in nature, and commonly found in the form of sodium and potassium salts. They constitute around 0.05% of the continental crust. The oceans have the greatest concentration of chlorides in the ecosystem. When chloride concentrations surpass 200 mg/l, water has an unpleasant and harsh taste, and there is a risk of oxidation of distribution networks. These ions are derived from the erosion of rocks and sedimentary soils, i.e. water disinfection and industrial operations that employ chloride as a cleaning agent (Papin *et al.* 2016).

The obtained results show that the average chloride ion concentration increased from 0.78 mg/l in 2019 to 13.3 mg/l in 2022 (94.14% increase). It was found that almost the same average concentration was found in Ras El-Ain natural ponds (13.7 mg/l). Furthermore, the water samples of the Jordan Valley have 261.8 mg/l in 2019. Drinking water disinfection levels should be within the range of 1.0 and 4.0 mg/l (Shrimanker & Bhattarai 2022). These values reflected the huge quantity of using sanitizers by farmers (fighting Coronavirus as per they thought). Nevertheless, it should be less than 0.5 mg/l for irrigation. The water's Alkalaa villages was suitable only for drinking in 2019, but it became not suitable neither for human consumption nor for irrigation in 2022. The same comment was concluded for the Tyr natural ponds and the Jordan Valley water.

Nitrites are formed as a result of the partial oxidation of organic compounds. Nitrites are present in most food items, the atmosphere, and the majority of water. Nitrites are formed as a result of the nitrification of nitrates. Once in the body, nitrites can react with iron inside the red blood cell 'hemoglobin', resulting in the formation of 'methemoglobin', and they are suspected of interacting with specific amino compounds. This is the case for amides and amines that combine to generate N-nitrosated chemicals, knowing that some of them may be carcinogenic (Konan *et al.* 2018). In 2019, the average concentration of nitrates was 0.3 mg/l in the Alkalaa villages. However, in 2022 this average decreased to 0.06 mg/l (80% decreased). This decrease is one of the constructed filters' benefits. In Ras El-Ain natural ponds, this concentration was found equal to 18.2 mg/l in 2022 and for the Jordan Valley 38.8 mg/l. The nitrites concentration in the Alkalaa village's water samples was acceptable for drinking and irrigation. In contrary to Ras El-Ain and Jordan Valley samples, they were greater than the WHO limit (1 mg/l).

Calcium is very common in nature. It is a mineral salt whose primary function is the mineralization of the bone in the form of calcium phosphate salts. Its most common sources in water are rocks and minerals, such as calcite. High calcium concentrations can cause bowel disease and kidney stones (Drake *et al.* 2020).

In 2019, all the sites in the various studied Alkalaa villages were free from any concentration of calcium. However, in 2022, the average calcium content became 136.6 mg/l (100% increased). Notice that the water sample taken from the S2 source was 276 mg/l, which presented a slight increase in the calcium concentration. In 2022, this cation had 112.5 mg/l average concentration in Ras El-Ain natural ponds and 106.7 mg/l for the Jordan Valley in 2019. These values are consistently below the limits specified by LIBNOR (300 mg/l drinking water standard) and FAO (400 mg/l irrigation water standard). This high value is another result of using fertilizers (since the soil properties will not change).

Magnesium is essential to the body. It participates in neuromuscular transmission, and is considered a natural 'anti-stress'. The most common source of magnesium is the weathering of rocks and minerals such as magnesite. High magnesium concentrations can cause cardiovascular disease and high water hardness (Wan *et al.* 2023).

The analysis of the water samples in the Alkalaa villages in 2019 showed the absence of magnesium concentrations in the various sites studied. In 2022, the average concentration rose up to 14.9 mg/l (100% increased). However, in 2022 this cation had a 22.8 mg/l average concentration in the Ras El-Ain natural ponds, and 58.08 mg/l for the Jordan Valley in 2019. The water samples in Ras El-Ain and in the Alkalaa villages are free from this contamination, since the obtained results were less than the WHO limit ($<$50 mg/l). However, the Jordan Valley samples exceeded slightly the drinking limit recommended by WHO, and irrigation (30–50 mg/l), which is another effect of fertilizers.

Lead is a bluish-gray chemical element, from the crystallin family, with atomic number 82. Native Pb is rare, it is associated with sulfide deposit, and it is extracted from its primary source: galena (PbS). This metal is easy to melt and form and has been used particularly for plumbing since ancient times. In the modern age, it was used to manufacture printing characters as an alloy with tin and antimony (Wu *et al.* 2023).

The lead in these sources comes from the corrosion of plumbing materials, such as pipes, valves, and fittings, as well as solder and well-casing materials, which are clearly observed through the installed water pipes. Lead poisoning has physiological and neurological pathological effects such as blood pressure disorders and the appearance of vascular and intestinal damage, as well as kidney disorders (Adhikari *et al.* 2023).

The average lead concentration in the Alkalaa villages source had 0.07 mg/l concentration in 2019. However, this average became 8.6 mg/l in 2022 (99.18% increased). Furthermore, this average was 0.26 mg/l in the Ras El-Ain ponds. In 2019, the water in the Alkalaa villages was acceptable for drinking water (<0.1 mg/l), and for irrigation (<5 mg/l). However, it became unsuitable for drinking and irrigation in 2022. The Ras El-Ain water samples were only acceptable for irrigation. However, there are no results for this cation in the Jordan Valley water samples. All the obtained results are summarized in Table 2.

Microbiological analysis

Microbiological parameters are the first to be taken into account when it comes to the drinking water supply because they can have effects on consumer health. The microbiological analysis makes it possible to highlight the fecal pollution of the water. For this reason, it is important to look for germs that are always present in large numbers in the faces of humans and animals which are more easily maintained in the external environment, which are TCs, fecal coliforms, *Salmonella* and *Shigella*. Note that the study achieved in Jordan did not have this analysis (Tarawneh *et al.* 2020). All the achieved microbiological tests and results are summarized in Table 3.

The term 'coliform' corresponds to organisms having the ability to grow in the presence of bile salts and capable of fermenting lactose with the production of acid and aldehyde within 48 h at temperatures of 35–37 °C. These bacteria have an intestinal origin (animal or human). They are frequently found in the environment, soil, vegetation, and water. These bacteria cause nausea, vomiting, and diarrhea and infect the lungs, skin, and eyes. The sources of this bacteria can be wastewater discharges, the presence of urban areas, or significant industrial activities (Hussain 2019).

The number of TCs in the Alkalaa villages varied between 0 and 20 CFU/100 mL (2019) and 0 and 100 CFU/mL (2022). The four sites: Ain El Hamam, Hamam filter, Ain El Bakar, and Ain El Tayta show that there is no pollution by TC. The highest concentration for the other sites (Ain El Mezrab, Ain El Warde, Ain El Jawze, and Artesian well) contaminated by TCs corresponds to site 1 and site 2 (Ain El Mezrab and Ain El Warde) which is equal to 100 CFU/100 mL (Table 3). All these

Table 2 | Physiochemical tests and results

			Alkalaa			WHO recommendations	
		Jordan 2019	2019	2022	Ras El-Ain 2022	Drinking	Irrigation
Pysical tests	pH	7.6	7.15	7.1	6.9	6.5–8.5	
	TDS	897	320	286	337.3	<300 mg/l	<500 mg/l
	EC	1,467.5	582.6	482.9	663	500 –1,000 μS/cm	
Chemical tests	Chloride	261.8	7.6	13.3	13.7	1–4 mg/l	0.5 mg/l
	Nitrites	38.8	0.3	0.06	18.2	1 mg/l	
	Calcium	106.7	0	136.6	112.5	100–300 mg/l	0–100 mg/l
	Magnesium	58.08	0	14.9	22.8	50 mg/l	30–50 mg/l
	Lead	0	0.07	8.6	0.26	0.1 mg/l	3 mg/l

Table 3 | Microbiology test results

		Bacteria types – culture media					
		Total coliforms Macconkey 37°		Fecal coliform Macconkey (*E. coli*) 44°		Salmonella Shigella agar 44°	
		2019	2022	2019	2022	2019	2022
Site 1	Ain El Mezrab	7	100	–	–	–	–
Site 2	Ain El Warde	20	100	–	–	–	600
Site 7	Ain El Jawze	18	–	–	600	–	–
Site 8	Artisian Well	2	–	–	–	–	–

concentrations exceed the WHO standards for drinking water (0 CFU/100 ml) and that of the FAO for irrigation water (100 CFU/100 ml). This pollution is visibly manifested by the discharge of wastewater without any efficient treatment in the Alkalaa Valley. In Ras El-Ain, this bacteria was found in all the natural ponds with values greater than the acceptable for drinking water (50 CFU/ml).

Fecal coliforms are a subgroup of TCs and show the same properties and characteristics after incubation at 44 °C. An important species in this group is *E. coli*. The presence of *E. coli* in the water is considered a positive indicator of contamination by human or warm-blooded animal fecal material. *E. coli* is an inhabitant of the intestines and stools of warm-blooded animals and folds. These bacteria cause bloody diarrhea, vomiting, and fevers and produce a powerful toxin that causes hemolytic uremic syndrome.

With regard to study sources in Alkalaa villages, all the sites do not show the existence of contamination by this type of bacteria (0 CFU/250 ml), except the site of the Ain El Jawze in 2022 (600 CFU/250 ml) shows high concentrations of this type of bacteria (250 CFU/250 ml), and the site of Ain El Jawze in 2022 (600 CFU/250 mL). These values exceed drinking and irrigation water limits (0 CFU/250 mL by WHO and 100 CFU/250 mL by FAO, respectively). However, in Ras El-Ain natural ponds, it has existed only within two natural ponds. This contamination is due to the leak of untreated domestic wastewater into the soil that pollutes the groundwater (some waste pipes are damaged and the waste smell is clearly around some distributed mainholes).

Salmonella is a very resistant bacteria of which there are two species but more than 2,500 serotypes. They can survive several weeks in a dry environment, and several months in water. They lodge in the intestines of infected people and animals, particularly poultry and reptiles. These bacteria are found in soil, food, and water (Liu *et al.* 2018).

Bacteria are transmitted through human-to-human or animal-to-human contact, or through the consumption of contaminated water and food. Most cases of bacteria spreading are associated with mishandling raw meats or eggs, or undercooking meats or eggs. Contact between cooked food and raw poultry on a cutting board or through the use of an unwashed knife can further contribute to the spread of *Salmonella* infection. Typically, symptoms appear one or two days after infection. Most people who get sick have diarrhea, abdominal cramps, headaches, nausea, vomiting, and fever. Symptoms usually last less than a week. However, some people can become seriously ill.

Based on the obtained results, all the sites in Alkalaa villages were free of Salmonella, except the Warde site. This bacteria revealed in 2022 (600 CFU/100 mL) and exceeded the drinking water limit set by the WHO (0 CFU/100 mL) as well as for irrigation water (0 CFU/100 mL) recommended by FAO (Table 3). Water pollution by *Salmonella* is explained by the flow of domestic wastewater observed in most sites. Besides that, for the Warde site, there are a few chicken unroofed farms not far from the source which affect directly the groundwater quality in this site. In addition, this bacteria did not appear in the Ras El-Ain natural ponds.

CONCLUSIONS

The study was carried out in the years 2019 and 2022 in the eight sources distributed within the Alkalaa municipalities union. The obtained results were compared with Ras El-Ain natural ponds (Lebanon) and the Jordan Valley (Jordan) to check the important role of environmental education locally and regionally in water conservation and preventing water pollution. Referring to the obtained results, the following points can be marked:

(1) The obtained results clearly show that the water in the Alkalaa Valley was significantly ionized and had greater amounts of ionic concentration behavior because of high soluble solids. Referring to the results obtained in 2022 to 2019, the average pH levels was found within the recommendation of the WHO. Furthermore, there is a decreasing in TDS value by 10.63% and EC by 17.15%. The chloride increased by 94.14%, the nitrites decreased by 80%, the calcium increased by 100%, the magnesium increased by 100%, and the lead increased by 99.18%. In 2019, four sites (site 1, site 2, site 7, and site 8) showed only the existence of CTs (7, 20, 18, and 2). However, in 2022, CTs were highly increased only in site 1 and site 2 with concentration equal to 100 CFU/100 mL and they disappeared from the other sites. Furthermore, fecal coliforms Macconkey (*E. coli*) appeared in site 7 (600 CFU/250 ml) and Salmonella Shigella agar in site 2 (600 CFU/250 ml).

(2) By comparing the previous results with that obtained for the Ras El-Ain samples, it showed that the concentrations of anions in 2019 were higher than in other areas (above the WHO standards for drinking water and for irrigation), due

to the excess use of fungicides and algicides for fighting the Coronavirus (the lack of habitant education in this field). Furthermore, the Jordan Valley samples were much higher for the same reasons.

(3) The cations concentrations were slightly high in the three investigated areas due to the precipitation (early April) so there will be more leaching from the rocks and the ions will sink further into the groundwater.

(4) Chloride was used with high concentrations during the Corona pandemic phase, within the three different areas. However, it does not solve the microbiological problems in the tested areas (Ras El-Ain and Jabal Amel Valley).

Water sources are continually exposed to pollution problems, sometimes on the physicochemical side, sometimes on the microbiological side, or to mixed problems that affect both sets. Water contamination can always be of natural or anthropogenic origin.

The main objective of this work is to determine the physicochemical characteristics of the eight water resources in the Bint-Jbeil district, within two different years. This research was achieved to check the effect of Corona on the behavior of the village inhabitants within this area and the obtained results were compared with other achieved research in the same country (Lebanon) and out of it (Jordan). It can be concluded by the following:

- The monitoring of the physicochemical parameters has shown that the physicochemical characteristics of the water are always within the ranges respecting the standards specified at the national and international level adapted for the water.
- The analysis of anions shows that the inhabitants were directly affected by the Coronavirus, and started cultivation of their lands (Ras El-Ain and Jordan Valley) without controlling the used amount of fungicides and algicides.
- The results of the microbiological analysis (Lebanon only) showed that the bacteria existed in several locations.

Due to the lockdown that accompanied the Coronavirus spreading, and facing the limitation of going more deeply to assess the water in the Alkalaa community (self funding in a worse economic situation and lack of studies), and referring to the obtained results, it can be concluded that the water distributed by these different sources is devoid of certain consumption safety measures. Water analysis is necessary to protect life (humans, animals and plants). Health can be improved by having better living conditions and a healthier environment.

The local authorities should participate in:

- Development of the policy in fighting the pollution at all social levels starting at the habitant and farmers levels. The absence of this policy leads to the excess use of fungicides and algicides without knowing the limitations and dangers of such excess. The inhabitants should be involved in the protection and conservation of water reserves (be careful when using fertilizers). In addition, it is necessary to encourage the inhabitants to install local treatment filters to purify the water to get rid of pollutants.
- Encouraging community participation and establishment of the infrastructures necessary to reduce pollution, especially waterborne. The periodical check of the water pipes system can prevent the appearance of many diseases, which can appear due to the dissolving of pipe materials in the drinking and irrigation water.
- Making effort to install several treatment plants. The absence of this policy probably pushed the municipality, due to the poor economic situation, to discharge their village sewages into the valley, the natural water channels. Such sewage will be absorbed by the soil and contaminate the groundwater, thereby polluting the water in the villages.
- Pollution protection measures should be applied at all times.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

REFERENCES

Adhikari, S., Lu, H. J. & Ng, D. Q. 2023 Lead levels in drinking water from point-of-use dispensers: A case study of elementary schools in Taichung, Taiwan. *Environmental Science and Pollution Research* **30** (37), 86846–86855. doi:10.1007/s11356-023-28475-z.

Blanc, P. 2006 Le Liban, l'eau, la souveraineté. *Confluences Méditerranée* **58** (3), 127. doi:10.3917/come.058.0127.

Daou, C., Salloum, M., Legube, B., Kassouf, A. & Ouaini, N. 2018 Characterization of spatial and temporal patterns in surface water quality: A case study of four major Lebanese rivers. *Environmental Monitoring and Assessment* **190** (8), 485. doi:10.1007/s10661-018-6843-8.

Drake, H., Kooijman, E. & Keilman-Schmitt, M. 2020 Using 87Sr/ 86Sr LA-MC-ICP-MS transects within modern and ancient calcite crystals to determine fluid flow events in deep granite fractures. *Geosciences* **10** (9), 345. doi:10.3390/geosciences10090345.

FAO 2022 *Food and Agriculture Organization: Irrigation with Treated Wastewater – User* Manual. Official Gazette No.5350 issued on 01/06/2016. FAO, Jordan, pp. 546–553.

Haddad, P. R. 2004 Ion chromatography. *Analytical and Bioanalytical Chemistry* **379** (3), 341–343. doi:10.1007/s00216-004-2572-7.

Hussain, M. S. 2019 Coli-form/E.coli in Water. In: *Conference: Water and Health Conference at Jacobabad, Pakistan*. doi:10.13140/RG.2.2.20062.38726.

Kassem, Y., Gökçekus, H. & Aljamal, J. 2020 Surface water resource and effect of weather parameters in estimating the annual rainfall: A case study in Lebanon. *IOP Conference Series: Materials Science and Engineering* **800** (1), 012028. doi:10.1088/1757-899X/800/1/012028.

Khatib, M., Daoud, M., Arairo, W., Saba, M. & Mortada, M. 2023a Evaluation of water quality in the South of Lebanon: Case study. *Water, Air, & Soil Pollution* **234** (410). doi:10.1007/s11270-023-06453-y.

Khatib, M., Daoud, M., Arairo, W., Saba, M. & Mortada, M. 2023b Water quality parameters assessment of Ras El Ain Natural Ponds, Tyr, Lebanon. *Water Supply* **23** (6), 2575–2585. doi:10.2166/ws.2023.140.

Konan, S., Goue, D., Yao, M., Kouame, K., Kouassi, L. & Dongui, K. B. 2018 Qualité Chimique des Eaux de Consommation des Populations de la Ville de Soubre (Sud-Ouest, Cote D'Ivoire). *International Journal of Approximate Reasoning* **6**, 58–65. doi:10.21474/IJAR01/6185.

Liu, H., Whitehouse, C. A. & Li, B. 2018 Presence and persistence of *Salmonella* in water: The impact on microbial quality of water and food safety. *Frontiers in Public Health* **6**. doi:10.3389/fpubh.2018.00159.

L'vov, B. V. 2005 Fifty years of atomic absorption spectrometry. *Journal Analytical Chemistry* **60**, 382–392. doi:10.1007/s10809-005-0103-0.

Mariner, N., Morhange, C., Borschneck, D. & Flaux, C. 2011 Holocene sedimentary sources in Southern Lebanon, Eastern Mediterranean. *Quaternary International* **266**, 105–116. doi:10.1016/j.quaint.2011.02.012.

Mohammad, F., Arfin, T., Saba, N., Jawaid, M. & Al-Lohedan, H. A. 2018 Electrical conductivity and biological efficacy of ethyl cellulose and polyaniline-based composites. *Electrically Conductive Polymer and Polymer Composites* 181–197. doi:10.1002/9783527807918.ch9.

Moumani, K., Abed, A. M. & Ibrahim, K. M. 2011 *Geology of Jordan – Field Guidebook*, 2nd edn. Jordanian Geologists Association, Amman, Jordan.

Mousavi, S. H., Kavianpour, M. R. & Alcaraz, J. L. G. 2023a The impacts of dumping sites on the marine environment: A system dynamics approach. *Applied Water Science* **13**, 109. doi:1007/s13201-023-01910-9.

Mousavi, S. H., Kavianpour, M. R., Alcaraz, J. L. G. & Yamini, O. A. 2023b System dynamics modeling for effective strategies in water pollution control: Insights and applications. *Applied Sciences* **13** (5), 9024. doi:10.3390/app13159024.

Nader, F. 2014 *The Geology of Lebanon*. Scientific Press, London, pp. 31–36.

Nassif, M. H. 2019 Analyse Multi-Scalaire des Politiques et de la Gouvernance de l'Eau dans le Bassin du Litani, Liban. Corpus ID : 226810448.

Nguyen, T. G., Phan, K. A. & Nhien Huynh, T. H. 2022 Application of integrated-weight water quality index in groundwater quality evaluation. *Civil Engineering Journal* **8** (11). doi:10.28991/CEJ-2022-08-11-020.

Papin, M. J., Gérard, J. R., Dossou-Yovo, P., Senou, S. F. & Modéran, T. R. 2016 Caractérisation Physico-Chimique et Microbiologique des Eaux Souterraines et Superficielles dans la Zone de Production Cotonnière d'Aplahoué. *Journal of Applied Biosciences* **103**, 9841–9853. doi:10.4314/jab.v103i1.6.

Postel, S. L., Daily, G. C. & Ehrlich, P. R. 1996 Human appropriation of renewable fresh water. *Science* **271** (5250), 785–788. doi:10.1126/science.271.5250.785.

Shammout, M. W., Shatanawi, K. & Abualhaija, M. 2023 Influence of population growth on supply, demand, and quality issues of water resources in the Yarmouk River Basin in Jordan. *Journal of Experimental Biology and Agricultural Sciences* **11** (1), 171–178. doi:10.18006/2023.11(1).171.178.

Shrimanker, I. & Bhattarai, S. 2022 Electrolytes. In: *StatPearls* [Internet]. StatPearls Publishing, Treasure Island, FL, USA.

Tarawneh, M. S. M., Janardhana, M. & Ahmed, M. M. 2020 Hydrochemical processes and quality assessment of groundwater in North Eastern Region of Jordan valley, Jordan. *HydroResearch* **2**, 129–145. doi:10.1016/j.hydres.2020.02.001.

Wan, D., Tang, R., Cao, S. & Zan, Q. 2023 Bibliometric analysis of magnesium and bone. *Journal of Innovations in Medical Research* **2** (6), 20–30. doi:10.56397/JIMR/2023.06.04.

WHO 2022 World Health Organization. Available from: https://www.who.int/news-room/fact-sheets/detail/drinking-water.

Wu, D., Hu, Y., Cheng, H. & Ye, X. 2023 Detection techniques for lead ions in water: A review. *Molecules* **28** (8), 3601. doi:10.3390/molecules28083601.

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