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Study of Physical and Chemical Parameters of Oustouan River, North Lebanon

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Abstract

The rivers of Lebanon have the peculiarity of having an environment of discharges of waste water from neighboring villages that line. Solid waste is also rejected in aquatic environment. The water flow varies considerably depending on the well defined seasons. Akkar region located in northern Lebanon is rich in agricultural land and waterways that should be monitored regularly to determine their physical and chemical and biological properties. This study is a need to detect contaminants of the Oustouan River and to push governments to better monitor streams and better protect them. We have studied the physical- chemical parameters of Oustouan River located at north Lebanon which is an area rich in agriculture, water represents a necessity for the people and for their activities. High levels of calcium (297.7 mg.L^{-1}) were observed at stations located at station E6 in June. However, Magnesium concentrations were low in April (0.327 mg.L^{-1}) and very high in all stations in August (4.23 mg.L^{-1}). High levels of sulfates (253.2 mg.L^{-1}) have been detected at station E6 in June. The high level of carbonates concentration at some stations has caused an important increase of the pH (from 7.8 to 8.5). Nitrate concentration 8.83mg.L^{-1} at the source increase to 13.96 mg.L^{-1} to the mouth of the river. The major problem of Oustouan River is the high concentrations of several minerals in particularly Chlorides and Sodium at E6. Heavy metals concentrations have been under the limit, in accordance with the method of detection by Atomic Absorption Spectrophotometer. This study should be repeated periodically to follow the water quality in the Oustouan River spacially at E6 sampling point and to define the possibilities of using its waters.

Keywords: Lebanese coastal waters; Akkar; Oustouan River; Environment status assessment; Physical-chemical parameters; Heavy metals

Introduction

Lebanon, with a total area of 10452 km^2 and a coastline length of 210 km from North to South, is located along the Eastern coast of the Mediterranean Sea [1]. The population was estimated to be about 4.5 millions in 2015 [2]. This number is no longer valid since the influx of Syrians who fled the civil war in their country. Given that Lebanon and Syria are two countries that share common borders.

The climate of Lebanon is typically Mediterranean, humid to sub-humid in the wet season to semi-arid in the dry season. The wet season coincides with winter period, which lasts from October till May [3].

Water provision is a major issue in Lebanon. Water withdrawal in this country, which is mostly used for irrigation, has increased by 20.5% since 1997, and is primarily drawn from surface waters (71.5%) with ground waters providing one fifth of the regions need [4]. However, current levels of water extraction are leading to the reduction of groundwater reserves at an alarming rate. The result of this has been reduced flows in the region's rivers and wetlands. Water pollution is also a major threat to freshwater biodiversity in the region and in the Mediterranean Sea. The main sources of pollution are from urban sewage and wastewater (often untreated), excessive pesticides and nutrients from agricultural activity (primarily nitrogen and phosphorus, and pesticides, fungicides, and herbicides), discharges and accidents from industrial facilities (including heavy metals and oils), and dumping of solid waste from a variety of sources. The physical loss of wetlands is also a significant pressure across the region of North Lebanon.

The Oustouan River is the most important national river in North Lebanon which takes its rise at an altitude of 1.500m near Kammouah Hills in Old Akkar. Called also Khreibi River, Population from several villages, such as Deir Jannine, Soueïssa and Khreibi el Jindi, use its water. Several years ago fisheries were the major activity in the water of this river. The Oustouan River has an area of 163 square kilometers (Table 1). Our attention has been attracted by this river to achieve an assessment in willing to develop the natural resources of North Lebanon. Water is one of Lebanon's most precious resources. Renewable resources in Lebanon have been evaluated by the Lebanese Ministry of water and energy at 2.7 million m^3 approximately in 2005 [5]. Of these 2.7 million m^3 annually available, 1.2 million m^3 flow into the Mediterranean, which leaves the final 1.5 million m^3 consumed as follows: 70% for the agricultural sector, 20% for domestic sector and 10% industrial sector Figure 1 [6].

North Lebanon has several perennial rivers and about 23 seasonal ones. They constitute renewable water resources, their combined length is approximately 730 km and their total annual flow averages 3,900 Mm^3. The main perennial rivers are characterized in Table 1 [7].

The Oustouan River is contaminated by waste water, the production areas of sea salts are installed on the banks of this river. Discharges of sewage waters are sighted at E4 which contributes to alter the quality of the river water and their organic enrichment. Our research on the physical-chemical water quality of the river has helped to highlight the extent of the pollution and the technical problems that cause pollution of the river. This study is a first for many years and it is very important for the north Lebanon region.

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River	Length (Km)	River catchment area (Km²)		Main springs inside the river Catchment area
		Inside Lebanon	Outside Lebanon	
Oustouan	44	163	0	Jawza, Fawar, Kabou, Gharbi
Arqua	27	131	0	Arouss, Ghara, Bizbina, Tineh, Yaacoub
Al-Bared	23.5	288	0	Kassim, Brissa, Sir
Abou Ali	44.5	478	0	Kadisha, Rach'ine, Mar Semaan, Mar Sarkis, Achach, Kadi, Moutran
Al Jaouz	38	189	0	Afqa, Roueiss
Al Kabir	60	297	644	Zarka, Laboueh

Table 1: Characteristics of Northern Lebanon's Perennial Rivers [7] (SEMIDE EMWIS: Euro-Mediterranean Information System on know-how In the water sector).

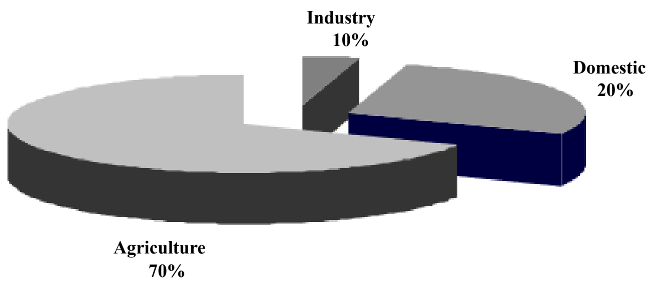

Figure 1: Water demand per sector in Lebanon [6].

Therefore, this paper aims to provide a study of physical and chemical parameters for Oustouan River from April to June. Assessing the water quality of the Oustouan River is an essential step to trace the settlement strategy of an important database of the Lebanon water surface quality.

The Figure 2 represents the location of Oustouan River at North Lebanon.

The climate

In Lebanon, precipitations constitutes the only renewable water resources; with annual average of approximately 840 mm. The long-term weather data indicate that 95% of the precipitation fall between October and April, and the remainder 5% between May and September [8]. Due to the topographical diversity of Lebanon, the climate varies considerably from region to region. The climate is Mediterranean, harsher in the mountains, hot and humid on the coast, semi-arid mountain desert in the Anti-Lebanon and continental in the Bekaa Valley. The Khamsin, hot, sandy desert wind, comes from Syria during March, but its passage is short. Snowfields persist throughout the year and snow can be several meters thick on the Lebanese mountains.

Mean annual temperature varies on the coast between 19.5°C and 21.5°C. It decreases approximately 3°C for each 500 m of altitude. The lowest temperatures are recorded in January, the highest temperatures in August [5]. The Table 2 represents the Mean Temperatures of the last 20 years registered in Tripoli, the city of North Lebanon [9].

Average annual rainfall is estimated at 823 mm although this varies from 700 to 1000 mm along the coastal zones and from 1500 to 2000 mm on the high mountains, decreasing to 400 mm in the eastern parts and to less than 200 mm in the northeast. Above 2000 m, precipitation allows essentially to sustain a base yield for about 2000 springs during the dry period. Precipitation in dry years can be as little as 50 percent of the average. Rainfall occurs on 80 to 90 days a year, mainly between October and April. About 75 percent of the annual stream flow occurs in the five-month period from January to May, 16 percent from June to July and only 9 percent in the remaining five months from August to December [4].

The Table 3 represents the Mean Values of the last 20 years of rainfall registered in Tripoli, the city of North Lebanon. Erosion is the consequence of torrential rain falls with devastating effects. Mass Movements are very common in Lebanon; they contribute to land degradation enhancing its superficial instability. Several layers of permeable limestone and clay enable the emergence of water springs, which influence the development of population activities [10].

Water quality constraints

In Lebanon, surface water is often contaminated by the discharge

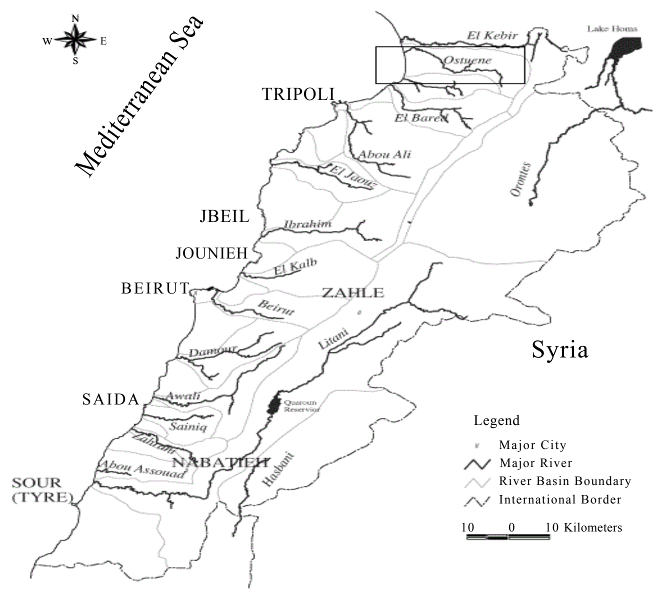

Figure 2: Hydric map of Lebanon and emplacement of the Oustouan river (Lebanese Ministry of Water and Energy).

Temperature	January	February	March	April	May	June
Max °C	17	17	18	21	24	27
Min °C	10	10	11	13	17	21
Temperature	July	August	September	October	November	December
Max °C	29	31	28	27	25	19
Min °C	22	24	22	18	16	12

Table 2: The Mean Temperatures and rainfall registered in Tripoli, the city of North Lebanon [9].

Rainfall	January	February	March	April	May	June
mm	180	160	220	90	...	...
Rainfall	July	August	September	October	November	December
mm	...	...	...	30	60	230

Table 3: Mean values of rainfall registered the last 20 years in Tripoli, North Lebanon [9].

of sewage water in rivers, springs and ground water. Surface water used for irrigation accounts for more than two-thirds of the water demand in Lebanon. Some agricultural practices as the excessive use of fertilizer have led to the contamination of surface and ground water. The uncontrolled disposal of solid wastes in watersheds has also led to the contamination of river basins due to the leaching of chemicals. Pollutants might also infiltrate through fissured bedrock and pollute the groundwater downstream of a dumpsite, increasing the width of the contaminated region [10].

Site description

This study is carried out in the region of Akkar in northern Lebanon (Figure 2). Oustouan River is a Lebanese river of 44 Km long and an annual flow of 65 mm^3. It is fed by several springs in Akkar at 1500 m of altitude and flows into the Mediterranean Sea at Cheikh Zennad, north of Tripoli at a few kilometers from the Lebanese-Syrian borders [8].

Sampling and parameters

The sampling has been done properly in order to obtain analyses results which accurately reflect the quality of water. Samples have been taken at various points along the river according to the accessibility of water and the nature of nearby agricultural and tourist activities. E6 was the nearest point to the Mouth of the Oustouan River (about one Kilometer, near the Syrian Territory borders). The Figure 3 represents the sampling stations map from the source Oustouan River.

Six samples have been taken Monthly at predefined time from Oustouan River for the duration of the study of linear streams. Samples were collected and transported to the laboratory in coolers (4°C), as soon as possible according to the norm NF T90-100.

The samples have been analyzed using certified methods ISO, AOAC and NF in the laboratory of the Lebanese Agricultural Research Institute (LARI) Abbdé–Akkar located in North Lebanon. Physical-chemical parameters have been measured to assess the quality of the water. These parameters are: pH, conductivity, Calcium, Magnesium, Sodium, chlorine, nitrates, sulfates, carbonates, and heavy metals: Iron, Lead, Mercury, Zinc, Chromium, Copper, Nickel, Aluminum, Cadmium, Manganese, Silver and Selenium.

For the analyses, the material used is: Laboratory current equipment, pH meter WTW 521 equipment with a combined electrode, a built-in thermometer and a magnetic stirrer. Dissolved oxygen was measured using a device of land WTW multiline F/SET-3. We have used an electrical conduct meter: field LF 91 unit equipped with automatic temperature compensation. SHIMADZU UV-Visible spectrophotometer has been used for salt concentration determination. Heavy metals have been detected by using a SHIMADZU Atomic Absorption Spectrophotometer equipped with several lamps for specific detection for each type of heavy metal. Atomic absorption spectrometer's working principle is based on the sample being aspirated into the flame and atomized when the AAS's light beam is directed through the flame into the monochromator, and onto the detector that measures the amount of light absorbed by the atomized element in the flame. Since metals have their own characteristic absorption wavelength, a source lamp composed of that element is used, making the method relatively free from spectral or radiation interferences. The amount of energy of the characteristic wavelength absorbed in the flame is proportional to the concentration of the element in the sample.

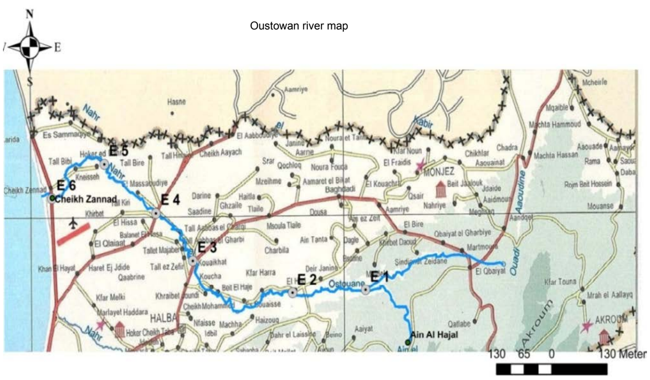

Figure 3: Oustouan River map (Lebanese Army, General Direction of Resources).

Results and Discussion

The different activities presented on the banks of the river have direct consequences on the quality of the river water. The samples taken to different points of the river course correspond to (Figure 3):

E1: No activities

E2: 3 restaurants along the river

E3: 2 restaurants along the river

E4: area where there are discharges of waste water with household waste

E5: farmland

E6: lot of salt marshes on the banks of the river

Study of Akkar region's weather

During the period of analysis, atmospheric temperatures and precipitation fluctuated from one month to another. Table 2 represents the temperatures: maximum and minimum air and water temperatures and precipitation during the duration of the analysis. The rain did not exceed 90mm during the 3 months of the study

Air temperature has a direct effect on the evaporation of water, the concentration of pollutants or their dilution, their diffusion in the air, dissolution in water and sedimentation at the bottom of the watercourse [11].

Temperature: The average of water temperature ranged from 18-27°C and varied proportionally to air temperature. They are compatible with microbial activities that can take place in the watercourse [11].

Our study was conducted in the spring. This season corresponds with the melting snow in the mountains, increasing the water flow in the rivers and elevation of atmospheric temperature.

Dissolved oxygen: Dissolved Oxygen (DO) in water is a very important parameter in water analysis as it serves as an indicator of the physical, chemical and biological activities of the water bodies. The two main sources of dissolved oxygen are diffusion of oxygen from the air and photosynthetic activity: Diffusion of oxygen from the air into water depends on the solubility of oxygen and other factors like water movement, temperature, salinity, etc. Photosynthesis, a biological phenomenon carried out by the autotrophy Bacteria, depends on the plankton population, light condition, gases, mineral substrate as Carbon and Nitrogen. DO is considered to be the major limiting factor in water bodies with organic compounds.

As DO concentration is close to saturation, the ability of the River to absorb the pollution increases. In the absence of DO, anaerobic bacteria take over to decompose organic material and unpleasant smelling due to gas such as H_2S, CH_4, NH_3 and amines. When water is overloaded with organic materials (waste water discharge), oxygen-consuming bacteria proliferate and DO decreases more rapidly than it can be replaced from the atmosphere.

Rates of dissolved oxygen in the studied streams were around 3 mg of O_2. L^{-1} while according to Table 4 should be between 8.11 and 9.76 mg of O_2. L^{-1}.

The solubility of oxygen decreases in water with increasing temperature [12].

pH: The effect of pH on the chemical and biological properties of liquids makes its determination very important. It is one of the most important parameter in water chemistry and is defined as -log [H^+], and measured as intensity of acidity or alkalinity. In natural waters pH is governed by the equilibrium between carbon dioxide/bicarbonate/carbonate ions and ranges between 4.5 and 8.5 although mostly basic. It tends to largely increase during the day due to the photosynthetic activity (consumption of carbon-dioxide) and decreases during night due to respiratory activity. Waste water and polluted natural waters have pH values lower or higher than 7 based on the nature of the pollutant [13].

Some important metals for the environment generate poorly soluble hydroxides in aqueous solution. Many metal ions can be precipitated in water with OH^- ions. Precipitation means forming a solid phase from two or more compounds which are normally ionic and dissolved. Such precipitation reactions are important in practice to remove metals such as aluminum, iron, chromium or copper (e.g. to prepare drinking water) from aqueous media. To determine whether, in a particular situation a metal can accumulate in sediments forming hydroxides with water, we have to know the conditions under which certain metals may be precipitates as hydroxides. Knowledge of the value of pH is essential to know if the metals remain in solution in water or if they are precipitated as hydroxides [13].

The pH of the samples registered from 7.86 at the source to 8.38 at the end of the watercourse (Figure 4) is consistent with high concentrations of carbonates in the water of Oustouan River.

Effects on aquatic life: Most freshwater lakes, streams, and ponds have a natural pH in the range of 6 to 8. Acid deposition has many harmful ecological effects when the pH of most aquatic systems falls below 6 and especially below 5. Here are some effects of increased acidity on aquatic systems:

- As the pH approaches 5, non-desirable species of plankton and mosses may begin to invade, and populations of fish such as smallmouth bass disappear.
- Below a pH of 5, fish populations begin to disappear, the bottom is covered with mosses which may dominate near shore areas.
- Below a pH of 4.5, the water is essentially devoid of fish.
- The most serious chronic effect of increased acidity in surface waters appears to be interference with the fish' reproductive cycle. Calcium levels in the female fish may be lowered to the point where she cannot produce eggs or the eggs fail to pass from the ovaries or if fertilized, the eggs and/or larvae develop abnormally.

When the pH of freshwater becomes highly alkaline (e.g. 9.6), the effects on fish may include: death, damage to outer surfaces like gills, eyes, and skin and an inability to dispose of metabolic wastes. High pH may also increase the toxicity of other substances. For example, the toxicity of ammonia is ten times more severe at a pH of 8 than it is at pH 7. It is directly toxic to aquatic life when it appears in alkaline conditions [14].

Electrical conductivity: The Electrical Conductivity (EC) of water estimates the total amount of solids dissolved in water, the electrical conductivity of the water depends on the water temperature: the higher the temperature, the higher the electrical conductivity would be. The electrical conductivity of water increases by 2 to 3% for an increase of 1 degree Celsius of water temperature. Many EC meters nowadays automatically standardize the readings to 25°C. While the electrical conductivity is a good indicator of the total salinity, it still does not provide any information about the ion composition in the water.

The conductivity is important because aquatic animals and plants are adapted for a certain range of salinity. Outside this range, they will be negatively affected and may die. Some animals can handle high salinity, but not low salinity, while others can handle low salinity, but not high salinity. In addition to its direct effects on aquatic life, salinity also has many other important effects on water chemistry and water density.

The Figure 5 describes the variation of the Conductivity of the samples; these values (from 580µS/cm at the source in April to 1560 µS/cm at the end of the watercourse on May) are consistent with high concentrations of ionic compounds in the water of Oustouan River.

Chemical oxygen demand (COD): Measurements of COD were very variable depending on the stations and the nature of water and waste dumped into the river. Discharges of sewage waters are sighted at E4 (Figure 12) which contributes to alter the quality of the river water and their organic enrichment. Our research on the physical-chemical water quality of the river has helped to highlight the extent of the pollution and the technical problems that cause pollution of the river.

T°C	Solubility mg of O_2.L^{-1}
0	14.16
5	12.37
10	10.92
15	9.76
20	8.84
25	8.11

Table 4: Decrease in the solubility of oxygen in water with increasing of temperature [12].

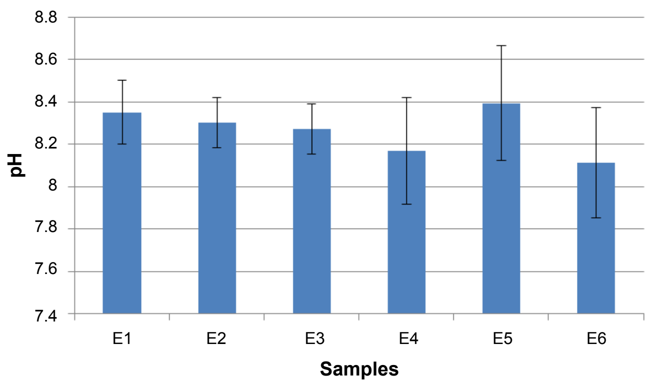

Figure 4: Variation of pH in different stations of Oustouan River.

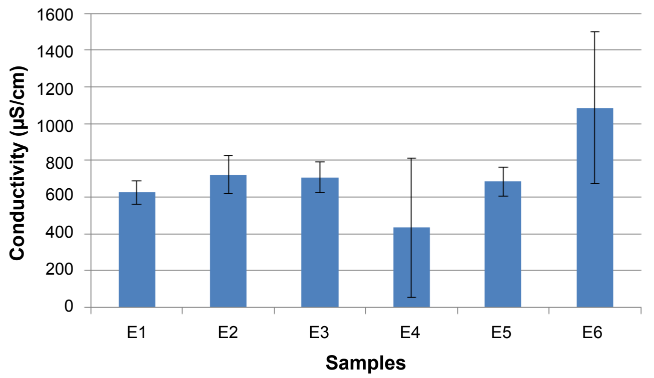

Figure 5: Variation of electrical conductivity (µS/cm) in water of Oustouan River.

The results varied enormously from one station to another (56.4 mg of O_2.L^{-1} at E1, 235.23 mg of O_2.L^{-1} at E4 and 128.87 mg of O_2.L^{-1} at E6) and the biodegradation along the water courses until the E6 station where very high concentrations of salts inhibit the activity of microorganisms conduct to accumulation of organic pollutants and their path to Mediterranean Sea.

Calcium and magnesium: The presence of calcium and Magnesium in water results from passage through or over deposits of limestone, dolomite, gypsum and such other calcium and magnesium bearing rocks. They contribute to the total hardness of water and are an important micro-nutrient in aquatic environment and is especially needed in large quantities by molluscs and vertebrates.

In the studied streams, the Calcium concentration was very high due to Calcium-rich rocks of Akkar.

The Figures 6 and 7 describe respectively the concentrations of Ca^{2+} and CO_3^{2-} in the waters of Oustouan River (from 195.3 mg. L^{-1} at E1 to 297.7 mg. L^{-1} at E6 for Ca^{2+} and from 200 to 321 mg. L^{-1} for CO_3^{2-}). In all our samples, the levels remained higher than the limit value. The erosion of the limestone rocks are responsible for these high values. The concentration of Ca^{3+} and Mg^{3+} give total hardness. It is equal to Magnesium, calcium and bicarbonates present in rivers that flow through the Mesozoic sediments (sediments Triassic, Jurassic and Cretaceous) [15].

Hardness of the water of Oustouan River is represented in Table 5.

During the three months of the study, i.e. from April to June, Mg concentrations were very low, not exceeding a mean value of 3.6 mg.L^{-1} (Figure 8). During these three months, melting snow and high water flow were at the origin of the dilution effect of the magnesium concentrations.

Mg-rich rocks are the main sources of this mineral element in water; magnesium components are widely used in industry and agriculture. It is also an important element contributing to hardness and a necessary constituent of chlorophyll. Its concentration greater than 125 mg/L can influence cathartic and diuretic actions.

Nitrate: Nitrate present in natural waters may have several causes: Either the activities of farmers using fertilizer high in nitrates to improve their crops or nitrifying activities of heterotrophic bacteria (ammonification) and autotrophic nitrous bacteria (formation of nitrite) and autotrophic nitrate bacteria (formation of nitrates). The discharges of sewage water into the river of Oustouan enrich the environment in germs and organic matter which will be oxidized to mineral compounds. Organic nitrogen is oxidized to ammonium which in turn will be oxidized to nitrite than nitrate. This chemical transformation consumes available oxygen in the water.

During the dry season, the water renewal of Oustouan River is low, the current speed is slow, the oxygenation of the water is weakened especially the consumption of oxygen by micro-organisms and macro

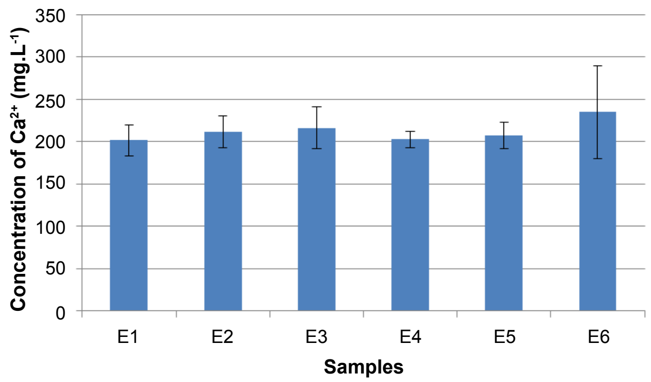

Figure 6: Concentration of calcium (mg.L^{-1}) in water of Oustouan River.

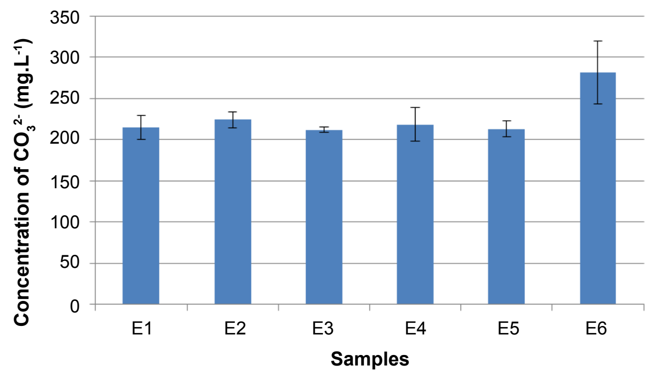

Figure 7: Concentrations of carbonates (mg.L^{-1}) of water of Oustouan River.

	E 1	E 2	E 3	E 4	E 5	E 6
April	48.8	50	49.25	49	48.57	49.195
May	46.75	50.25	51.5	49.55	50.1	52.5
June	55.46	58.22	50	8.65	56.125	74.4

Table 5: Hardness of water in Oustouan River (mg.L^{-1}).

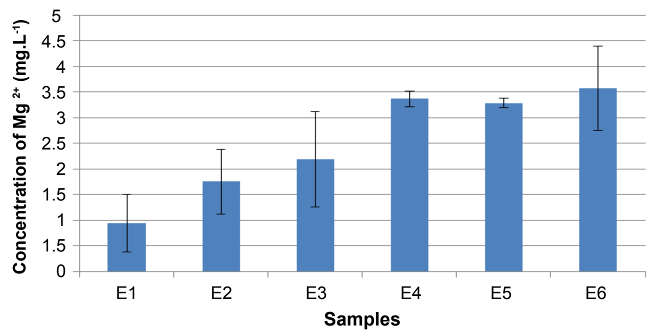

Figure 8: Concentrations of Magnesium (mg.L^{-1}) in water of Oustouan River.

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organisms is important. This situation can lead to eutrophication of the river concomitant with excessive production of nitrates in the environment.

The Figure 9 describes the evolution of Nitrate all over the Oustouan River during the three months of the study. Nitrate values change from 8.83 mg.L^{-1} at E1 to 13.96 mg.L^{-1} at the sample E6. At this point the concentrations of nitrates are not very high, because the water dilution effect is prevalent.

Sulfate: Sulfate is found appreciably in all natural waters, particularly those with high salt content. Besides industrial pollution (fossil fuel burning that leads to the formation of acid rain), and domestic sewage, biological oxidation of reduced sulphur species also adds to sulfate content. The sulfate concentration is only partially correlated to sulfate contents contained in the rocks. Soluble in water, it imparts hardness with other cationic ions. Sulfates are a part of naturally occurring minerals in some soil and rock formations that contain groundwater.

Sulfate minerals can cause scale buildup in water pipes similar to other minerals and may be associated with a laxative effect on humans and young livestock. Sulfate gives a bitter taste, a medical water taste if it exceeds the concentration of 250 mg. L^{-1}. This makes unpleasant water consumption [16]. Important concentrations of sulfate can be corrosive to pipes particularly copper. In places where there are large concentrations of sulfate, it is common to use anti-corrosive material, such as plastic pipes.

The Figure 10 describes the evolution of sulfate concentrations from the source E1 (127.3 mg.L^{-1}) to E6 before the end of the water cross (253.2 mg.L^{-1}). Values registered at the mouth of the river are considered high as many other parameters analyzed at E6 in the watercourse.

Chlorides: The presence of chlorides in natural waters, in general, can mainly be attributed to dissolution of salt deposits in the form of ions (Cl^-). Otherwise, high concentrations may indicate pollution by sewage, industrial wastes, intrusion of seawater or other saline water. It is the major form of inorganic anions in water for aquatic life. High chloride content has a deleterious effect on metallic pipes and structures, as well as agricultural plants.

Figure 11 shows a clear difference between the concentrations of chlorides at the source E1 (13.7 mg.L^{-1}1) and those around 1km before the mouth at E6 (270 mg.L^{-1}) of Oustouan River. It was impossible to reach the mouth of the river very close to the Syrian territory borders.

Several pools of desalination of sea water are installed along the edge of the Oustouan River (Figure 14). Analyses of samples collected at point E6 in the Oustouan River next to desalination basins show a saltwater leak in the stream. The high rate of salts has a direct impact on water quality, on raising the bottom of the river levels following sedimentation. The living organisms in the river are the first affected by the change of physical - chemical environmental parameters such as pH, salt concentrations in particular chloride, sulfate and metal salts.

The sodium concentrations confirm this point of view because they increase sharply at the same point E6 as the chlorides (Figure 13).

Heavy metals: The metals are natural components of the Earth's crust. They are trained in waterways due to leaching from agricultural land. Discharges of fertilizers and industrial wastewater into surface waters enrich the environment with heavy metals.

Heavy metals cannot be degraded or destroyed. To a small extent they enter our bodies via food, drinking water and air. As trace elements (oligo elements), some heavy metals as copper, selenium and zinc, are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning. Heavy metal poisoning could result, for instance, from drinking-water contamination (e.g. lead pipes), high ambient air concentrations near emission sources, or intake via the food chain. Heavy metals are dangerous because they tend to bioaccumulation. Compounds accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted. Heavy metals

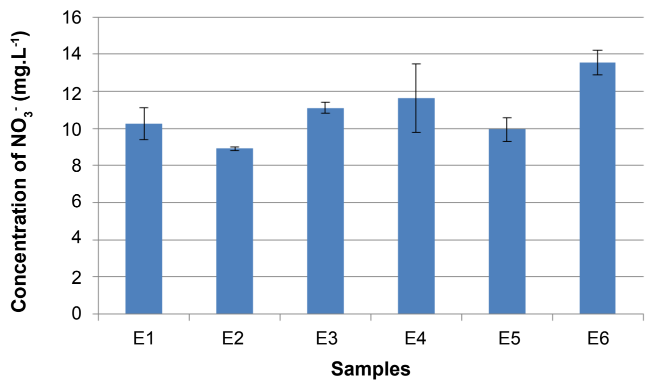

Figure 9: Concentrations of Nitrate (mg.L^{-1}) in water of Oustouan River.

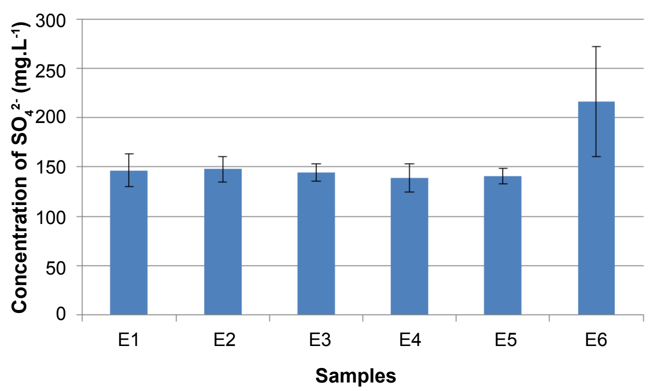

Figure 10: Concentrations of Sulfates (mg.L^{-1}) of water of Oustouan River.

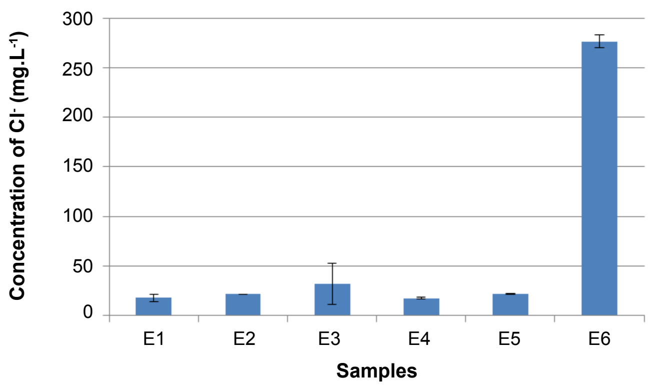

Figure 11: Concentrations of Chloride (mg.L^{-1}) of water of Oustouan River.

Figure 12: Discharge of waste water in the Oustouan River (the pipe of discharge appears clearly).

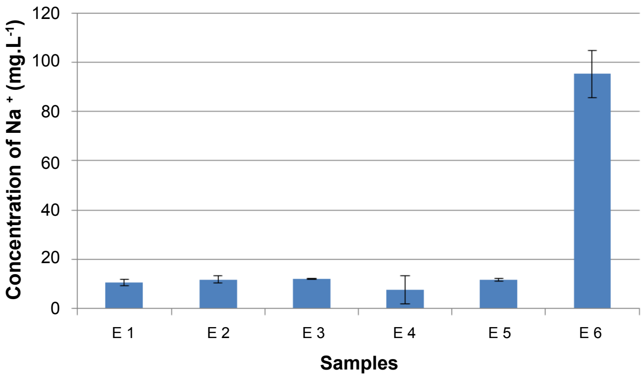

Figure 13: Concentrations of Sodium (mg.L^{-1}) of water of Oustouan River.

can enter a water supply by industrial and consumer waste, or even from acidic rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater.

Table 6 exposes our analysis results of Heavy metals in water of Oustouan River. We are particularly interested to toxic metals such as mercury, cadmium, lead, Nickel, Zinc and Aluminum and copper. Our results showed their presence to trace (lower limits of detection of the analytical method).

Given that the pH is higher than 8. Heavy metals, even if they exist in the stream are in the form of metal hydroxides and are not in free form in water. For this reason, their concentration is at state of trace.

Biological Analysis

Dia and Dumont in 2011, have recorded 5 dragonfly species at Oustouan River [17]:

- *Aeshna mixta*
- *Caliaeschna microstigma*
- *Calopteryx. S. syriaca,*
- *Pseudagrion syriacum,*
- *Sympetrum striolatum*

Our study shows a rich presence of fecal Coliforms and *Streptococcus fecalis* all along Oustouan River except at the source. The discharge of waste water is the main source of fecal Coliforms and *Streptococcus fecalis* (Figure 12).

Conclusion

The District of Akkar in the North of Lebanon is predominantly agricultural. Water needs are very important in this region for irrigation of agricultural land, for tourism and industrial activities. The number of residents has increased the last 5 years, given the remote Akkar Syrian borders. The influx of Syrian refugees has increased water needs throughout the country. The Oustouan river water is a necessity for the people of Akkar. The sustainability of water in Lebanon is due to the lengthening of the dry season from May to October as precipitation is the only renewable water sources. Particular attention should be paid to the preservation of river water to meet the needs of population.

The analysis carried out on the waters of River Oustouan showed an enrichment of dissolved salts throughout the course of the river from the source to the mouth. The concentrations of carbonates and calcium, magnesium and sulfates have increased at E6 nearest sampling point to the mouth of the river. There is a close correlation between geological composition of the watershed and the composition of the water.

This shows an enrichment of salts due to a weakening of the water flow. The measured conductivity proves enrichment since the values were multiplied by 2.6 at E6.

Element	E1	E6
iron (mg.L^{-1})	< 1	1.75
lead (mg.L^{-1})	< 0.01	< 0.01
Mercury (µg.L^{-1})	< 1	< 1
Zinc (mg.L^{-1})	< 0.01	< 0.01
Chromium (mg.L^{-1})	< 0.01	< 0.01
Copper (mg.L^{-1})	< 0.01	< 0.01
Nickel (mg.L^{-1})	0.02	0.01
Aluminum (mg.L^{-1})	< 0.01	< 0.01
Arsenic (mg.L^{-1})	< 0.01	< 0.01
Cadmium (µg.L^{-1})	< 1	< 1
Manganese (mg.L^{-1})	< 0.01	< 0.01
Silver (mg.L^{-1})	< 0.01	< 0.01
Selenium (mg.L^{-1})	< 0.01	< 0.01

Table 6: Concentration of heavy metals in water of Oustouan River.

Figure 14: Dessalination pools on the right edge of Nahr Oustouan near the Lebanese-Syrian border.

The values of chlorides and Sodium have increased at E6 sampling point such as many other parameters; this is due to the intrusion of water from the desalination pools at the edge of Oustouan River. This pollution is added to many others such as sewage solid waste and erosion of farmland.

The most important properties of Oustouan water to be used for irrigation are:

- The concentration of potentially toxic elements, especially heavy metals such as mercury, cadmium, Aluminum, Zinc and Nickel.
- The pH of water must be between 6.5 and 9.
- The concentration of Carbonate.
- The total concentration of soluble salts.

Special attention must be worn on Oustouan River against desalination pond leakage situated on the edge of the river about one Kilometer before the mouth.

Heavy metal concentrations are negligible; they are accompanied by an alkaline pH which is no risk of leaching in case of adsorption on sediments. This point will be clarified in a subsequent search to be carried out on the sediments and their nature.

The Mediterranean countries must act together by conducting a permanent protocol analysis to protect the waters of the Mediterranean Sea from polluted water effluents that flow from rivers in neighboring countries.

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