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Suitability of Surface Water for Domestic Water Use: Awali River Case Study

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Abstract: The Arab Region is currently challenged by securing sufficient water resources for sustainable development. Although, Lebanon is considered relatively "the reservoir of water in the Middle East", still, the provision of adequate, sustainable safe domestic water remains a major challenge to be met. The city of Beirut hosts one third of the Lebanese population due to progressive urbanization, resulting mostly from centralization of services and economic activities. Faced with this challenge, the tendency is to reduce dependency on groundwater resources and supplement it by surface water. The Awali River is among the 16 perennial flowing water resources, at a relatively convenient distance from the Capital (Beirut). The objective of this work is to evaluate the river water basin to determine the optimal extraction points, water quality variability and the need to develop and sustain proper river basin management and quality control programs. Accordingly, water samples were collected throughout the year from identified sampling locations. Complete physical, chemical, microbiological (pH, Conductivity, TDS, TOC, Ca, Mg, HCO3, SO4, NO3, Na, K, Fe, Zn, Cu, Pb, Cd, Mo, Co, *Total Coliform, Ecoli*) quality profile based on standard methods and procedures were conducted. Further data was analysed using SigmaStat statistical package and water modelling software AquaChem. Preliminary results reflect on minimal exposure to sources of pollution other than domestic sewage. This further emphasizes the need to meet the water and sustainable goals of the water for life decade 2005-2015. Moreover, promoting and sustaining water and sanitation projects becomes a real challenge.

Key words: Awali River, Domestic water supply, integrated river basin management, water modelling, water quality.

1. INTRODUCTION

The Arab region is currently challenged by securing sufficient water resources for sustainable development. As such the water sector is receiving increasing attention among policy makers and development agencies in the region. For example the World Bank devoted its regional development report of the Middle East in 2007 to water sector development (World Bank, 2007). The Islamic Development Bank (IDB) commissioned a special report on water availability in the member countries to mark its 30th anniversary (IBD, 2005). Additionally, the Arab Human Development Report for 2009 addressed in a special issue water security challenges in the region (UNDP, 2009). At present, the available annual per capita of renewable water resources in Arab countries is among the lowest in the World (World Bank, 2007). The Arab Forum for Environmental Development projects that mostly all Arab countries will suffer, as early as 2015, severe water scarcity reducing the annual per capita share to less than 500 m^3 which is less than one-tenth of the World's average of 6,000 m^3 (AFED, 2010; UNDP, 2009).Moreover, thirteen Arab countries do currently rank among the World's nineteen most water-scarce countries (per capita water availability in eight countries is below 200 m^3 and drops to below 100 m^3 in six countries) (UNDP, 2009, AFED, 2010).

Although Lebanon has been considered for years relatively "the reservoir of water in the Middle East", still the provision of adequate, sustainable safe domestic water remains a major challenge to be met. The annual renewable per capita water availability was 1100 m^3 in the year 2006 (above water scarcity level-of 1000 m^3/capita/year). Still, it is projected that amounts will drop below the water scarcity levels by 2015 (990 m^3/capta/year), will descent further more by 2025 (919 m^3/ capita/year) (AFED, 2010).

This is mostly due to the fact that current patterns of water consumption are unsustainable mostly due to the progressive growth in population, industrial development and centralization, and expansion of irrigated agriculture. At present, the available water resources (river flow and ground water) are estimated at 2,000 Mm^3/year. In the year 2000 the water demand (1,392 Mm^3/year) was lower than the water supply. Currently, the water demand (1,905 Mm^3/year) is nearly equal to the water supply, but by the year 2015, Lebanon will be confronted by water supply deficit with the increase in demand to 2, 286 Mm^3/year, and progressively by 2025 the water deficit will amount to 1,069 Mm^3/year**.**

At the domestic level, the increase in population ($2.6x10^6$ in the year 1990; $3.6x10^6$ in 2000 (40% increase); currently $4.1x10^6$; and $4.6x10^6$ by 2025) will greatly increase the domestic water demand (AFED, 2010). Furthermore, the concentration of population in urban areas has increased the per capita water demand, specifically for the city of Beirut that hosts about two-thirds of the Lebanese population ($\cong 2.4x10^6$ citizens), and is striving to provide the amounts of needed domestic water (Korfali and Jurdi, 2009). Still, water shortage, intermittent water distribution and dependency on complementary water sources (private wells) prevail.

The excessive exploitation and deterioration of fresh water aquifers of Beirut city has been tackled extensively (Korfali and Jurdi, 2007, Korfali and Jurdi, 2009, Korfali and Jurdi 2010). Attempts to address this chronic issue have led to conduct feasibility studies on surface water bodies. Those technical studies have recommended the construction of 16-20 dams in various parts of country to increase the overall water storage capacity (Amery, 2002). Still, to present only one dam has been completed. Additionally, direct intake from rivers is also under study. The Awali River is the major water source being to complement the escalating domestic water demand for the city of Beirut. The Council for Development and Construction (CDR) and World Bank have engaged the MWH Engineering Firm to update the 1994 feasibility study and prepare a project cost estimate for the transfer of water from the Awali River to the capital -Beirut (MWH, 2010). Hence, this work is intended to complement the existing efforts with the objectives of evaluating the river basin water quality and quality variation and accordingly determine the optimal extraction points, and propose a comprehensive river basin water quality management plan and quality control programs.

2. MATERIAL AND METHODS

2.1 Study Area - Awali River

The Awali River is a perennial river flowing in southern Lebanon. It is 48 km long, originating from the Barouk Mountain at a height of 1,492 m and Niha Mountain. The Awali River is supplemented by two tributaries (Barouk River and Jezzine River). The meeting point of the two tributaries is at Bisri, where flows unite in one stream forming the Awali River, which then flows westward and discharges into the Mediterranean Sea (north of Saida city). The Awali River basin area is of 294 km^2, with an annual river discharge of 299 Mm^3, and an average water flow of 10.1625 m^3/s (ECODIT, 2001).

The rocks outcropping in Awali basin, as presented in Figure 1, belong to Jurassic, Cretaceous, and Quaternary system. Most of the rocks are of karsts formation of the Cretaceous system (C2b and C4), Jurassic system outcrop upstream in Barouk River, Barouk Mountain. The Quaternary deposits (q) are of less extent consisting of silt, sand and gravel (adapted from geological maps of Dubertret, 1955).

2.2 Sampling Sites and Sampling Methodology

The Awali basin was screened to update the sources of pollution reported by an earlier surveillance activity conducted in 2008-2009 (Abdul Massh, 2010). Accordingly, the sampling locations were reassessed. The sampling points extended from river sources to the river discharge point as presented in Figure 1. No major industrial activities were identified along the river basin and mostly sources of pollution are reflected by sewage discharge, leachate of solid waste dump sites, agricultural runoff, and wastes from recreational areas.

Water samples were collected from the 16 identified sampling sites, during both the dry (June, July and August 2010) and wet (January, February and March 2010) seasons. Samples were collected at mid depth from surface using 1 L polyethylene bottle. Also, 300 mL water samples were collected in borosilicate glass bottles for bacteriological analysis. Water sampling and transportation was done in accordance with the recommendations of the Standard Methods for the Examination of Water and Wastewater (APHA , 1998).

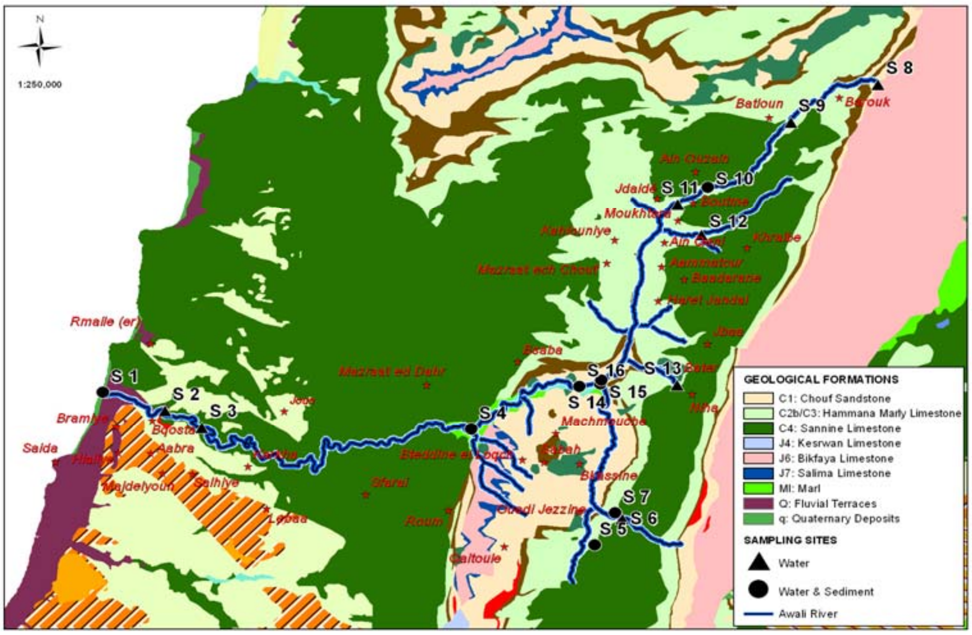

Figure 1. Geological map of studied area (after Dubertret), and sampling sites.

2.3 Field Measurements

Parameters sensitive to environmental changes were measured on site. Temperature, electrical conductivity (EC_W), and total dissolved solid were measured using Hach Model 44600 Conductivity/TDS Meter and pH using Hach Pocket pH Model (calibrated before measurement, Conductivity/TDS by sodium chloride solution, pH with two standard solutions with pH 4.01 and 10). Dissolved oxygen (DO) was measured by membrane electrode.

2.4 Laboratory Analysis

The analysis was conducted at the Water Quality Assessment and Management Research Unit at Lebanese American University (joint project in collaboration with the Lebanese National Council for Scientific Research and The American University of Beirut).

Each water sample was filtered through 0.45 μm pore size membrane filter and divided into two water sub-samples.

The first set of water sub-samples (250 ml) was acidified to pH < 2 with nitric acid and then stored at 4^{o}C for the analysis of Na and K by flame photometer technique ("Thermo" FISHER PFP7) and trace metals (Fe, Zn, Cu, Pb, Cd, Mo, Ni) by AAS-Graphite furnace ("Shimadzu" AA-6300) and background correction deuterium lamp. The second set of water sub-samples was used for the immediate analysis of the total organic compound (TOC) using TOC Analyzer (“Shimadzu” VCPN); alkalinity using the standard (0.02 N H_2SO_4) procedure; Ca, Mg and total hardness using the standard (0.01 M EDTA) method; SO_4^{2-} (turbidimetry) and PO_4^{3-} (ascorbic acid) by spectro-photometric method “HACH” Odyssey, DR, 2500); Cl^- by Ion Chromatography (“Shimadzu” PIA-100) and the biochemical oxygen demand(BOD) based on 5 day incubation at 20°C. Additionally, the bacteriological analysis was performed by membrane filtration technique (Millipore).

2.5 Software Used in Analysis

The statistical analysis of the physio-chemical parameters was performed using statistical package SigmaStat. AquaChem software was used to predict water type, macro elements rock source, and the PHREEQC Geochemical model interfaced with AquaChem to predict metal species.

3. RESULTS AND DISCUSSION

3.1 Water Quality Assessment-Macro Chemical Profile

Table 1 and Table 2 present the mean values of the physio-chemical parameters that characterize the water quality of the Awali Basin. The statistical difference (one sample t test) among the different sampling dates of the dry and wet seasons were insignificant. Thus, the data reflects on the mean temporal and spatial concentrations of the studied parameters. Also, the spatial ranges, standard deviation, and significant differences (P) of sampled sites are presented in the indicated tables.

The mean temperature of dry season was 19°C (ranging between 13 and 24 °C); and the mean of the wet season was 13°C (ranging between 9 and 16°C). The order of the macro-elements concentration for the dry and wet seasons was as follows: for cations $Ca^{2+} > Mg^{2+} >$ Na+, and for anions $HCO_3^- > Cl^- > SO_4^{2-}$. However, for some sites (sites 6 and 11), during dry season, SO_4^{2-} levels were higher than Cl^- levels. This order is illustrated in Figure 2 (Piper Diagram) of the major cations and anions concentration for all sites of studied area. This observed order can be attributed to the prevalence of carbonate sedimentary rocks (Stumm and Morgan, 1996; Jurdi et al. 2002, Korfali and Davies, 2004) in the Awali drainage basin. Moreover, AquaChem software predicted Ca-Mg-HCO_3 water type for the dry season. At some sites the water type was Ca-Mg-HCO_3-Cl or Ca-Mg-HCO_3-SO_4. The mean concentrations of Ca and Mg in the dry season were respectively 125 mg/L and 22.6 mg/L. While the mean concentrations of Ca and Mg in the wet season was respectively, 44.5 mg/L and 12.6 mg/L. Hence, the dilution effect on the mean levels of Ca and Mg in the wet season becomes evident.

Moreover, the paired sample t-test did not reflect on any seasonal statistical significant differences for Ca ($P= 0.21$). On the contrary, Mg exhibited significant seasonal difference ($P= 0.002$). This can be explained by the thermodynamic stability of dolomite that renders Mg solubility to be different; solubility should have increased at lower temperatures (Drever, 1997; Korfali and Davies, 2003). In conclusion, the presence of Ca and Mg is lithogenic, and this is further indicated by AquaChem prediction of source of rock type (calcite and dolomite weathering). Furthermore, the PHREEQC geochemical model also predicted positive saturation indices during both seasons for calcite and dolomite.

In regard to Cl^-, the mean concentration for the dry season was 78.5 mg/L ranging between 20 and 700 mg/L. This high upper range concentration was determined at the discharge point of river in the Mediterranean (site 1) reflective of the mixing of sea water with freshwater. Additional source may be due to sewage disposal prevailing at this site. Also, the chloride level at site eleven was high (80 mg/L); this site is located amid agricultural and farm activities. On the other hand, the mean concentration of Cl in the wet season was 32.7 mg/L, ranging between 20 and 55 mg/L.

Paired sample t-test showed no statistical significant difference (P= 0.239) in levels of chlorides between the dry and the wet seasons and the detected levels, for both seasons, were below the maximum permissible level of 250 mg/L recommended by WHO (2006) guidelines and USEPA (2011) standards for drinking water (Table 3).

Table 1. Water quality of the Awali River (dry season, 2010)

Parameter	SD	%CV	Min	Max	Mean	T Value	P level
Temperature ^{o}C	3.15	18.4	13	24	19	0.19	0.852
pH	0.417	5.5	6.8	8.2	7.6	0.012	0.991
Cond. µS/cm	609	99	250	2410	610	0.004	0.997
DO (mg/L)	0.86	11.3	5.87	9.61	7.62	0.11	0.194
BOD (mg/L)	1	122	0.01	4.00	0.81	0.007	0.04
TOC(mg/L)	3	26	2.15	15.1	11.5	0.53	0.04
HCO_3(mg/L)	38	18	141	307	227	-2.86	0.012
Ca(mg/L)	21	17	84	168	125.5	0.093	0.917
Mg(mg/L)	8.2	36	7.2	40.8	22.6	0.044	0.996
Na(mg/L)	7.9	252	0.5	33	3.1	0.003	0.998
K(mg/L)	0.007	134	0.01	0.32	0.006	0.051	0.961
NH_3-N(mg/L)	0.004	22.4	0.10	0.21	0.14	0.079	0.938
NO_3-N(mg/L)	0.48	69	0.10	2.1	0.71	0.051	0.960
SO_4(mg/L)	36	77	5	120	47	-0.007	0.995
Cl(mg/L)	146	186	20	700	78.5	0.012	0.991
PO_4(mg/L)	0.46	62	0.06	1.71	0.74	3.48	0.003
Fe(µg/L)	9.54	23.5	23	59	40	9.85	0.001
Zn(µg/L)	34.4	49	12	133	69	0.015	0.989
Cu(µg/L)	3	86	0.6	12	3.4	0.075	0.941
Mo(µg/L)	0.35	15.5	1.6	2.8	2.22	0.014	0.989
Ni(µg/L)	1.56	23	3.9	9.8	6.7	0.018	0.986
Pb(µg/L)	1.21	82	0.07	4.1	1.46	0.031	0.976
Cd(µg/L)	3.12	45	2	14	6.89	0.112	0.912
Ecoli			0	TNC			

Table 2. Water quality of the Awali River (wet season, 2010)

Parameter	SD	%CV	Min	Max	Mean	T Value	P level
Temperature ^{o}C	2.02	15.1	9	16	13	23.9	0.001
pH	0.17	11.9	6.5	7.1	6.7	1.3	0.216
Cond. µS/cm	52	11.9	316	516	441	0.012	0.918
DO (mg/L)	1.1	13	7.06	10.58	8.5	22.2	0.001
BOD (mg/L)	2.29	78.69	0.45	8.14	2.29	0.001	0.999
TOC(mg/L)	2.28	19.39	10	21	15.4	0.006	0.995
HCO_3(mg/L)	42	18.47	141	337	228	0.014	0.989
Ca(mg/L)	7.8	8.2	84	108	94.5	0.215	0.834
Mg(mg/L)	10	80	2.4	33.6	12.6	0.001	0.999
Na(mg/L)	0.13	28	0.3	0.7	0.45	0.175	0.864
K(mg/L)	0.003	46	0.001	0.01	0.006	0.557	0.585
NH_3-N(mg/L)	0.04	17.9	0.17	0.31	0.24	0.587	0.568
NO_3-N(mg/L)	0.225	44.6	0.1	0.8	0.51	-0.03	0.997
SO_4(mg/L)	10.3	40	7	40	25.8	0.024	0.981
Cl(mg/L)	11.5	35	20	55	32.7	-1.295	0.232
PO_4(mg/L)	0.23	36.5	0.37	1.08	0.62	0.049	0.962
Fe(µg/L)	12.3	37.5	15	52	33	0.002	0.998
Zn(µg/L)	32.3	56.2	23	139	57.5	-0.003	0.997
Cu(µg/L)	1.1	75	0.11	4.4	1.5	0.018	0.986
Mo(µg/L)	0.83	158	0.11	2.4	0.53	0.037	0.971
Ni(µg/L)	101	14.5	4.84	8.67	6.94	0.006	0.996
Pb(µg/L)	0.41	44	0.6	1.6	0.94	0.034	0.971
Cd(µg/L)	2.7	51	2	12	5.4	0.010	0.992
Ecoli C/100mL			0	TNC			

The prime source of Cl is natural as indicated by the AquaChem software predication (rock weathering) except at site 1 (river discharge into the sea). Similarly, the prime source of sulfate is natural; the mean level for the dry season was 47 mg/L (ranging between 5 and 120 mg/L) with the upper range levels detected at site eleven, and site one (114 mg/L). Still, the mean sulfate levels, for both seasons, were below the maximum permissible level of 250 mg/L recommended by WHO guidelines and USEPA standards for drinking water (Table 3).

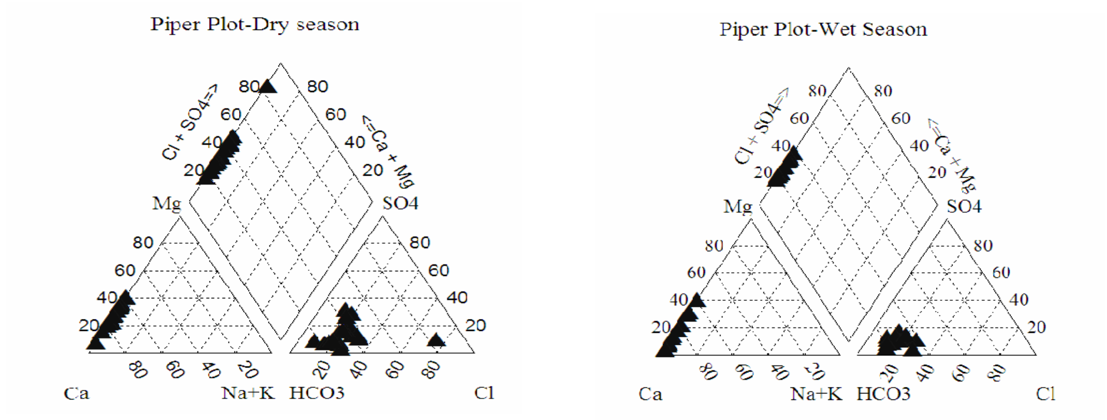

Figure 2. Piper Diagram of macro-elements distribution for all sampling sites

Table 3. International guidelines for drinking water (WHO, 2006, USEPA, 2011)

Parameter	pH	Cond. µS/cm	SO4 mg/L	Cl mg/L	Fe µg/L	Zn µg/L	Cu µg/L	Mo µg/L	Ni µg/L	Pb µg/L	Cd µg/L
WHO	6.5-8.5	1250	25-250	250	50-200	100-5000	100-3000	70	20	10	3
USEPA	6.5-8.5	-	250	250	300	5000	1000	70	13	5	5

Given the above presented water profile, the mean electrical conductivity (EC_W) for the dry season was 610 µS/cm, ranging between 250 and 2410 µS/cm with the upper range level detected, as expected, at the river mouth (site 1). Additional, the mean electrical conductivity (EC_W) for the wet season was 441 µS/cm, ranging between 316 and 516 µS/cm. Based on WHO (2006) guidelines for drinking water (upper limit of 1250 µS/cm), the Awali water quality is acceptable. Moreover, the EC_W levels showed statistical significant correlation with HCO_3 levels ($r=0.983$, $p < 0.01$) and Cl^- ($r=0.986$, $p < 0.01$) for the dry season. While in the wet season statistical significant correlation was established only between ECw and HCO_3 levels ($r=0.833$, $p <0.01$). These correlations confirm that the water mineral content is mostly resulting from natural sources.

As for the pH levels, the mean of the dry season was 7.6, ranging between 6.8 and 8.2, and for the wet season was 6.7, ranging between 6.5 and 7.1. Paired sample t-test showed statistical significant difference between the pH levels of the dry and the wet seasons ($P= 0.001$). Though in the dry season the pH level is alkaline, which is typical of water bodies underlain by carbonate rocks (Stumm and Morgan, 1996, Korfali and Davies, 2003), yet the pH level is lower than that reported for other Lebanese rivers (Korfali and Davies 2003, 2005; Houri and El Jeblawi, 2007). Further, it was expected that due to dilution by rain, the pH level of the wet season will be higher than that for the dry season (Korfali and Davies, 2003, 2005). But results of this study revealed the opposite as presented in Figure 3. Nevertheless, the detected pH seasonal variation is in agreement with other patterns reported by similar studies (Ekeh and Sikoki, 2003, Anasa et al. 2007, Abowei, 2010).

The lower pH values for the wet season are due to the increase of the organic load (organic wastes and/or decomposition of terrestrial vegetation) that was oxidized to give CO_2, thus increasing the hydrogen ion concentration and decreasing the pH level. Additionally, this offsets the the hydrogen ions input from surface run-offs during the wet season (Anasa et al., 2007, Abdullahi et al, 2008, Araoye, 2009, Abowei, 2010).

As such, the prevailing pH profile is not only an outcome of rock drainage basin; but, is additionally impacted by the increase in the organic load. A strong inverse significant correlation existed between pH values and BOD ($r= -0.720$, $p < 0.05$) for the dry season and for the wet season the inverse correlation was more statistically significant (r= -0.890, p <0.01). Similarly, statistical significant inverse correlation occurred between pH and TOC for the dry season (r= -0.689, p< 0.01). For the dry season, the mean BOD level was 0.81 mg/L, ranging between 0.01 and 4.00 mg/L. Also, one sample t-test showed statistical significant difference (P=0.004) among the studied sites. The BOD levels in the wet season were higher than those of the dry season (Figure 3). Likewise, the one sample t-test showed statistical significant difference (P= 0.001) among the sites. Furthermore, the paired sample t-test showed seasonal statistical significant difference (P=0.027) in the BOD levels. Likewise, the levels of total organic carbon (TOC) in the wet season were higher than those of the dry season (Figure 3), and paired t-test demonstrated seasonal statistical significant difference (P= 0.027) in TOC levels.

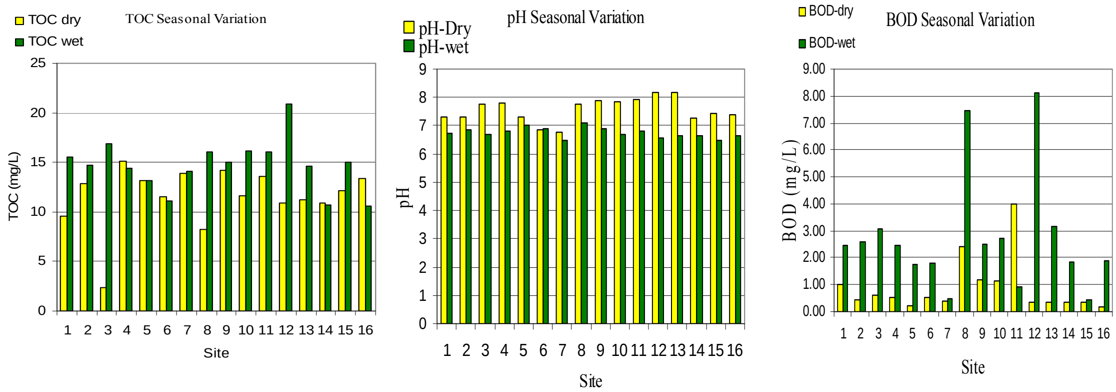

Figure 3. Seasonal variation of pH, BOD, TOC among studied sites

3.2 Water Quality Assessment-Metal Profile

Evaluating the profile of trace metals in Awali River basin, as presented in Tables 1 and 2 indicate minimal levels of most metals. Moreover, the levels of all detected metals are below the maximum permissible levels specified by the WHO (2006) and the USEPA (2011) standards for drinking water (Table 3).

The only exceptional metal was cadmium. Cadmium levels were higher than permitted levels by WHO (3 μg/L) guidelines and USEPA (5 μg/L) standards for drinking water. The mean Cd level for the dry season was 6.89 μg/L (ranging between 2 and 14 μg/L) and for the wet season 5.4 μg/L (ranging between 2 and 12 μg/L). The highest recorded levels for the dry season was at site one (waste dump), followed by site three and site 11. For the wet season, the highest detected Cd levels was at site 11 followed by site 5. These indicated sites are mostly characterized by agricultural activities.

Thus, the source of Cd in this study is most probably due to the excessive application of fertilizers as indicated in other works (Eriksson, 1990; Bogdanovic et al., 1999, Pérez and Anderson, 2009), since the geological formation of studied area is mainly limestone form (Figure 1), and recent unpublised study by Korali and Jurdi of levlels of metals (XRF technique) in different rocks of studied area, revealed that Cd was below detection limit. Besides, fertilizers applied in lebanon are mainly supplied by the Lebanese Chemical Company (LCC) that produces and markets a range of phosphate based fertilizers, including Simple Super Phosphate (SSP) fertilizer and Triple Super Phosphate (TSP), chemical formula of both is $Ca(H_2PO_4)_2.H_2O$, but % of P_2O_5 in TSP is 45 and in SSP is 16. Conducted study by Green Peace Laboratories (Bridgen et al., 2002) reported that SSP and TSP fertilizers contained cadmium at 4 and 7 mg/kg respectively, significantly above typical soil background levels of below 1 mg/kg. Additional verification to source of Cd in our study to fertilizers is projected by the statistical significant correlation between Cd and PO_4 for the dry season (r= 0.653, p <0.01), and for the wet season (r=0.711, p< 0.01).

Furthermore, the chemical soluble forms of Cd species (inorganic complexes and free hydrated cadium ions) predicted by PHREEQC Geochemical model and consequent toxicity, appeared to be of different pattern than those existing in other water bodies in Lebanon. The most bioavailable and toxic form of Cd is the free hydrated ion $Cd^{2+}(aq)$. Due to higher pH values in prevous studies, speciation of Cd as free aqua ion was reduced and speciation as the less toxic carbonate ion pair $CdCO_3^o$ increased (Korfali and Jurdi, 2003, Korfali and Davies 2004, Korfali and Jurdi, 2011). However, in this study with pH levels of 6.8–8.2 for the dry season, pH of 6.5-7.1 for the wet season, Cd was rendered to speciate mainly as free hydrated ion; percentage of $Cd^{2+}(aq)$ from total metal concentration was greater than 90%. Hence, it is critical to determine the level of total metal and speciated metal forms in solution when assessing surface water, as this will reflect on the potentail toxicity of the water and required intervention to ensure the safty of extracted water.

3.3 Water Quality Assessment-Microbiological Profile

Evaluating the microbiological profile, fecal coliform (*E.Coli*) were detected in both wet and dry seasons emphasizing sewage discharge and the leachate of the municipal solid waste dump sites as the major sources of microbiological contamination. This finding restricts domestic water use based on WHO guidelines and USEPA standards (0 *Ecoli C/100mL*).

In conclusion and based on water quality and water quality variability among the sampling sites, no optimal water extraction points can be defined. Water extraction should be only impacted by site accessibility and over-all cost of water extraction and delivery.

4. AWALI BASIN WATER QUALITY MANAGEMENT PLAN

Given the presented physical, chemical, and microbiological water quality profile of Awali basin, the following is recommended to upgrade and sustain water quality for domestic water use:

- Upgrade sewage management; sewage constitutes the main source of pollution, as such increasing the coverage of sewage networks becomes a must. Concurrently, sewage treatment plants should be constructed and should become operational. Care should be taken to devise treatment beyond the primary level to decrease the overall suspended solids and BOD levels,
- Management of agricultural run-offs; It is critical to base the application of fertilizers based on the nutrient content of the soil. Excessive application of fertilizers and the progressive use of raw sewage for irrigation is leading to the built up of Cd levels in water,
- Management of industrial wastewater; at present, this is of minimal concern due to the absence of such major facilities. Still, once such activities prevail, onsite treatment of the industrial waste water effluents should be properly implemented to protect water quality and ecologic wellbeing,
- Water treatment; Awali River water cannot be used to complement the escalating increase in domestic water needs, for the capital Beirut, without treatment. The treatment process should include primary sedimentation, coagulation/ settling and filtration to reduce on the suspended inorganic and organic load. Additionally, activated carbon beds can be integrated as part of filtration beds or as separate units. This is essential to control levels of TOC before the application of water disinfection by chlorine. Furthermore, advanced water treatment by ion-exchange beds is a must to remove the excess levels of Cd (major health threat), and
- Water quality monitoring programs; sustainable programs are essential and should reflect on:
  a) Monitoring the water quality of the river basin to determine the extent and effectiveness of the implementation of the recommended interventions that are mostly directed toward the management of domestic waste water (sewage) and agricultural runoff. This is crucial to ensure and sustain the ecologic well being of the river basin and consequently its water quality, and
  b) Monitoring the quality of the treated piped domestic water supply to ensure the control

of the overall total organic load, removal of cadmium, and the proper disinfection to insure the safety of the delivered domestic water supply.

5. CONCLUSION

This study has assessed the water quality of Awali River and its potential feasibility for domestic usage. The chemical profile reflects acceptable water quality conditions, but on exposure to agricultural run offs and sewage discharge. As such, it is critical to insure the control of fertilizers use, mostly in developing countries, that contribute to toxic trace metals, mostly cadmium that renders the water unsuitable for multi-purpose use. Additionally, meeting water and sanitation millennium goals is a must to insure the proper collection and treatment of sewage effluents challenging water viability. Hence, there is an utmost need for development and sustaining proper river basin management and quality control programs to meet domestic water shortages in Lebanon.

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