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LITANI RIVER BASIN MANAGEMENT SUPPORT PROGRAM

WATER QUALITY SURVEY – DRY SEASON (SUMMER 2010)

VOLUME 1 – MAIN REPORT

FEBRUARY 2011
This report was produced for review by the United States Agency for International Development (USAID). It was prepared by International Resources Group (IRG) under Contract EPP-I-00-04-00024-00 order no 7.

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ACRONYMS

AUB	American University of Beirut (LRBMS subcontractor)
BAMAS	Basin Management Advisory Services (similar survey funded by USAID and conducted in 2005)
BOD	Biochemical Oxygen Demand
EPA	Environmental Protection Agency (USA)
ES	Electrical Conductivity
GIS	Geographic Information System
GOL	Government of Lebanon
IQC	Indefinite Quantity Contract (contracting mechanism for USAID)
IRBM	Integrated River Basin Management
IRG	International Resources Group (US consulting firm, prime LRBMS contractor)
IWRM	Integrated Water Resources Management
LRA	Litani River Authority (also called Office National du Litani)
LRBMS	Litani River Basin Management Support Program
M&E	Monitoring & Evaluation
MEW	Ministry of Energy and Water
ONL	Office National du Litani (also called Litani River Authority)
TDS	Total Dissolved Solids
ULB	Upper Litani Basin
USAID	United States Agency for International Development
WHO	World Health Organization

FOREWORD

This water quality survey was carried out by a team led by Dr Mey Jurdi from the American University of Beirut (AUB) under subcontract with IRG, the main contractor under the Litani River Basin Management Support (LRBMS) Program, a USAID-funded program in Lebanon (Contract EPP-I-00-04-00024-00 Task Order No. 7 under the Integrated Water and Coastal Resources Management Indefinite Quantity Contract (IQC) II.

Apart from the main text which details both methodology and results, an Executive Summary presents the main findings, conclusions, and recommendations, while detailed results are provided as appendices. Only appendix I is provided in this volume while other appendices are in volume 2.

EXECUTIVE SUMMARY

INTRODUCTION-CONTEXT OF STUDY

This study was conducted as part of the efforts of the International Resource Group (IRG) under the USAID/Lebanon funded Litani River Basin Management Support Program (LRBMS) to assist the Litani River Authority (LRA) in upgrading and improving the management of Upper Litani Basin (ULB).

As such, the objectives of the study are to update the water quality inventories that were conducted in 2005 under the USAID funded activity of the Litani Basin Advisory Services (BAMAS) by:

a) Evaluating the ULB water quality profile,
b) Comparing to the results of the previous USAID-funded study (BAMAS 2005),
c) Reflecting on possible risks associated with multipurpose water usage, and
d) Recommending interventions for improved practices and mitigation/control measures for the main sources and types of pollution.

INITIAL FIELD SURVEY

Field and reconnaissance surveys were conducted for a period of 16 days (July 9-30 2010).

The **upper zone**, stretching between Saidi and Rayak, is characterized by a mixed residential, agricultural, and industrial profile. Four major tributaries feed into it; two of which are dry in summer. The river flow is minimal, only sustained by sewage and industrial wastewater effluents. Management of municipal solid waste is highly deficient; open dump sites are scattered throughout the area. Additionally, sanitary sewer systems and cesspools are the main venues for sewage disposal. A wastewater treatment plant (secondary/biological treatment) located in El Ferzol is operative; another treatment plant in Ablah is still under construction. Agricultural activities mostly relate to tobacco plantation, wheat and seasonal vegetables. Dependence on sewage and ground water for irrigation is high. The main industrial activities are dairy plants, food processing plants, rock cutting industries, plastic and paper industries. Industrial wastewater effluents are discharged directly into the river and its tributaries, or are disposed into the city/village sewer that outflows into the surface water body.

The **middle zone**, from Rayak to Aammiq, is also a mixture of residential, agricultural, industrial and recreation areas. The river flow is again minimal and is heavily exposed to sewage and industrial wastewater discharge. The water is blue green in color due to the extensive growth of algae. Five major tributaries contribute to the river flow yet are, in summer, either dry or completely tapped for irrigation.

A major landfill used for the disposal of solid wastes is located in Zahle. Yet, open dumping is still practiced by many cities/villages. As for the management of domestic wastewater, sanitary sewer systems (mostly) and cesspools (minimally) are the main venues of disposal. Additionally, a sewage treatment (secondary/biological) plant located between Housh Al Oumara and Bar Elias is under construction. Agricultural activities mostly relate to growing of seasonal vegetables with excessive dependence on sewage as irrigation water. This zone is characterized by an active industrial sector: dairy plants, food processing plants, water bottling industry, wineries, paper industries, dyeing and tanning, manufacturing of batteries, food packaging materials *etc*. Still, industrial wastewater is directly discharged into the river, or disposed into the municipal sanitary sewer that outflows into the river. Also, this zone is known for its restaurants and hotels mainly in Chtoura, Zahle and Anjar.

The **lower zone** from Ammiq to Qaraoun is also a mixture of residential, agricultural and to a lesser extent industrial, recreational and aquaculture farming areas. The river starts with minimal water flow supporting extensive algae growth and some presence of fish, water snakes, turtles, ducks etc. Tributaries are almost dry up in summer, or are tapped for irrigation. The river then flows into the Qaraoun Lake with relatively more water flow due to some resurgences and again sewage flows and return flows from agriculture. The management of municipal solid wastes is deficient. Sewage disposal is mostly through sanitary sewer systems and minimally through cesspools. Currently, a major sewage treatment plant in Jeb Janine is under construction. Agricultural activities relate to fruit trees (mainly vineyards). Agricultural lands mostly depend on Irrigation Canal 900 that directs water from the Qaraoun Lake, across the villages. This zone has minimal industrial activities like sugar cane industries, car repair shops, and paper industries, dyeing and tanning. Industrial wastewater effluents discharge into the river either directly or through the city/village sanitary sewer that outflows into the river.

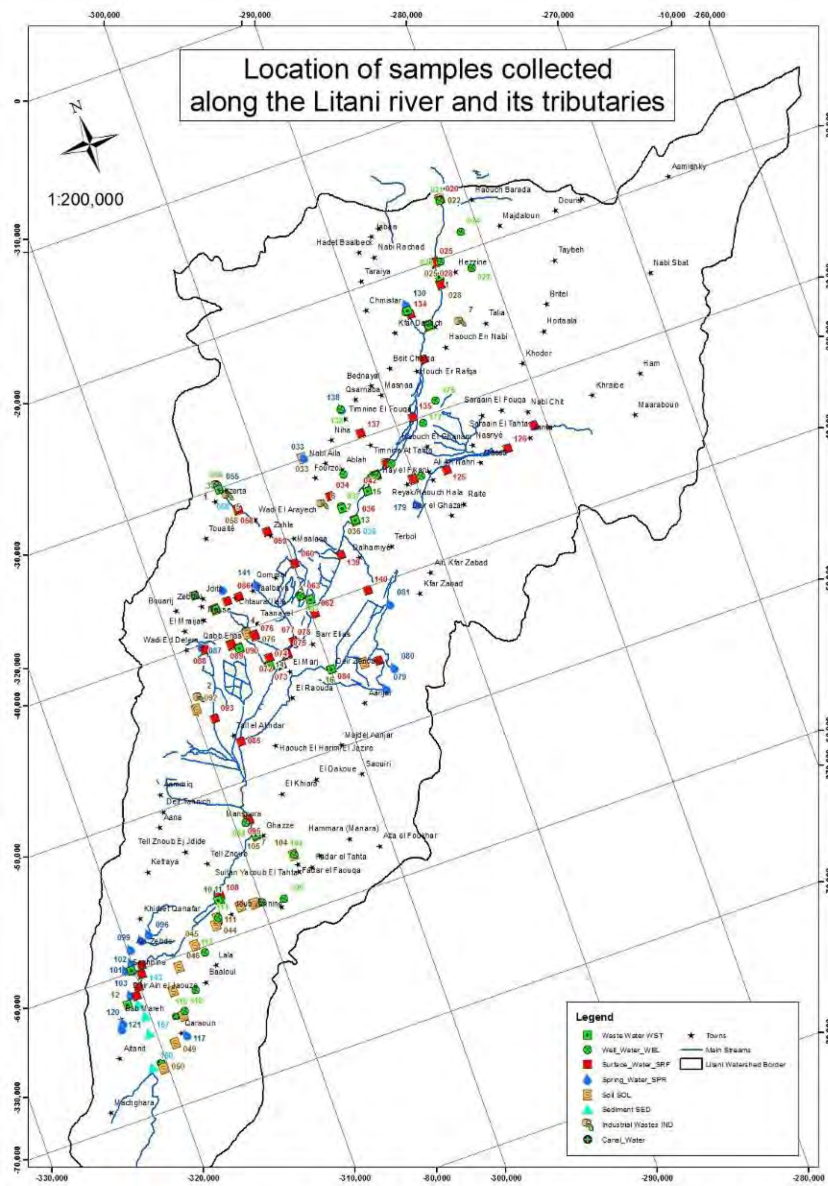
METHODOLOGY

A total of 149 Samples were collected during this study, over a period of 22 days (August-September 2010), from:

(a) The Litani river and its tributaries (26),
(b) The Qaraoun Lake (10),
(c) The Irrigation Canal 900 (7),
(d) Groundwater springs and wells located within the ULB (43),
(e) Sewage effluents from residential areas located along the river water flow (12),
(f) Major industrial wastewater effluents disposing directly into the river (7),
(g) Soils of agricultural areas bordering the river and irrigation canal (36), and

(h) River and lake sediments (8).

The types and location of samples are presented in figure 1. All samples were collected, transported, and analytically tested following standard methods and procedures. Complete physical, chemical and microbiological (total dissolved solid, electric conductivity, dissolved oxygen, biochemical oxygen demand, pH, alkalinity, ammonia, nitrates, phosphates, sulfates , chlorides, potassium, calcium, magnesium, sodium, lead mercury, cadmium, chromium, nickel, copper, zinc, iron, aluminum, arsenic, barium, cobalt, boron, manganese, molybdenum, organochlorines, organophosphorous, total coliforms, fecal coliforms and fecal streptococci) quality assessment was conducted. Additionally, analytical results were compared to BAMAS 2005 data to reflect on possible changes in water quality with time.



KEY FINDINGS - SURFACE WATER

Results (see table below) show a significant deterioration in the quality of the river water as compared to BAMAS 2005. This is evident by the:

- Increase in biological contamination (tenfold increase in BOD) resulting from the discharge of untreated sewage and the leachate of municipal solid waste dump sites and boosted by the discharge of untreated industrial wastewater into the river and its tributaries,
- Increase in chemical contamination (170% increase in TDS and shift of pH towards alkalinity) mostly reflective of continuous exposure to domestic and industrial wastewater discharge despite efforts to increase the sewerage system coverage; and
- Decrease in microbiological loads, dispite the continious exposure to wastewater, mainly due to reduced oxygen levels, decreased water flow and prolonged exposure to sunlight UV radiation.

Table: Comparison of **<u>Surface Water</u>** Quality Profiles Reported by BAMAS and Present Study 2010

Indicator	BAMAS (summer)2005 calculated from surface water results			Study (summer)2010 surface water results			Drinking water standard	
							MoE Lebanon	EPA
	Min	Mean	Max	Min	Mean	Max	25^{0}C	
[1]Total Disolved Solids (mg/l)	88	290.96	706	187	502	1979	<500[8]	<500
[2]pH (pH units)	6.57	7.09	7.68	7.27	7.93	8.66	6.5-8.5	6.5-8.5
[3]Biochemical Oxygen Demand (mg/l)	2	48.46	624	2.50	547	2530	NA	NA
[4]Nitrates (mg/l as N)	3	13.46	62	0.10	1.23	4.90	<10	<10
Phosphates (mg/l)	0	11.75	197	0.00	8.58	72	NA*	NA
[5]Fecal Coliform (CFU[11]/100ml)	0	223,487	150,000	1	71.61	400	0	0
[6]Cadmium mg/l	NA	NA	NA	0.005	O.01	0.079		<0.005
[7]Manganese (mg/l)	NA	NA	NA	0.01	0.07	0.27		<0.05

* NA: Not Applicable

<u>Definition of indicators:</u>

1.TDS: measures mineral content; reflects on the type of water source and exposure to pollution. Increased levels in surface water represent mostly increased exposure to sewage, industrial wastewater effluents, leachate of municipal solid waste dump sites and agriculture run off.

2. pH: measures alkalinity or acidity; agricultural runoff and sewage shift the pH towards alkalinity.

3. BOD: measures oxygen needed by aerobic microorganisms to treat organic pollution; high BOD reveals pollution from sewage and inefficient wastewater treatment, agribusiness effluents and excessive application of organic fertilizers.

4. Nitrates: measures presence of nitrates which causes algae growth and impacts aquatic life. Sources of nitrates are mostly nonpoint-source runoff from heavily fertilized croplands. High nitrate presence is improper for domestic use.

5. Fecal Coliform: measures sewage discharge. Decreasing levels found by the survey (as compared to BAMAS) are due to reducing conditions no supporting development of fecal organisms, not decreased discharge of sewage.

6. Cadmium and Manganese: trace metal indicators that measure exposure to agriculture runoff (increased use of pesticides and fertilizers)

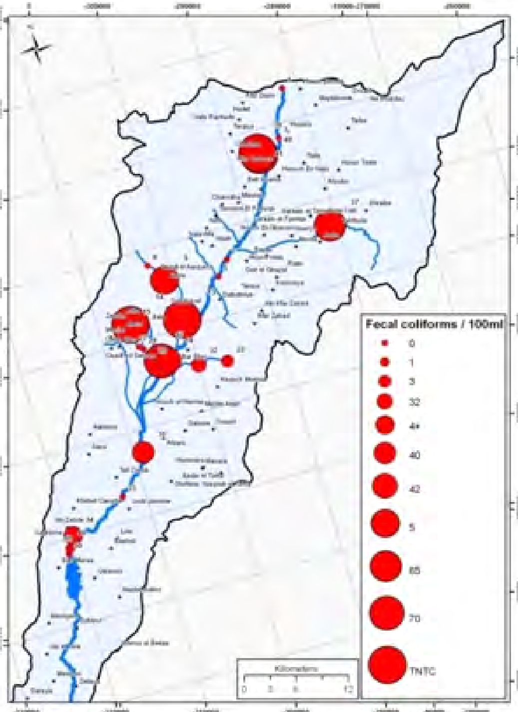


Figure1: Feacal Coliforms Along the Litani River and its Tributaries

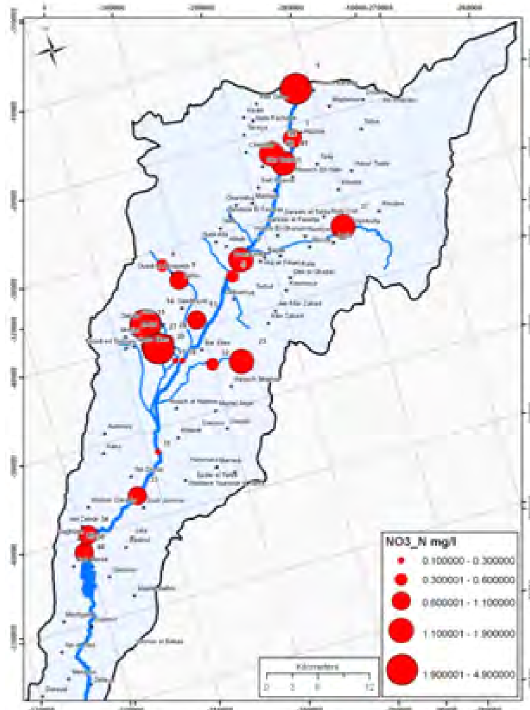


Figure 2: Nitrates Levels Along the Litani River and its Tributaries

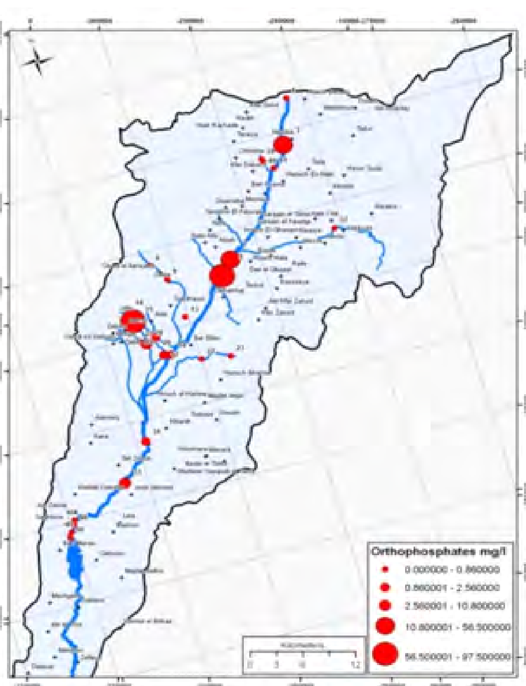


Figure 4: Phosphates Levels along the Litani River and its Tributaries

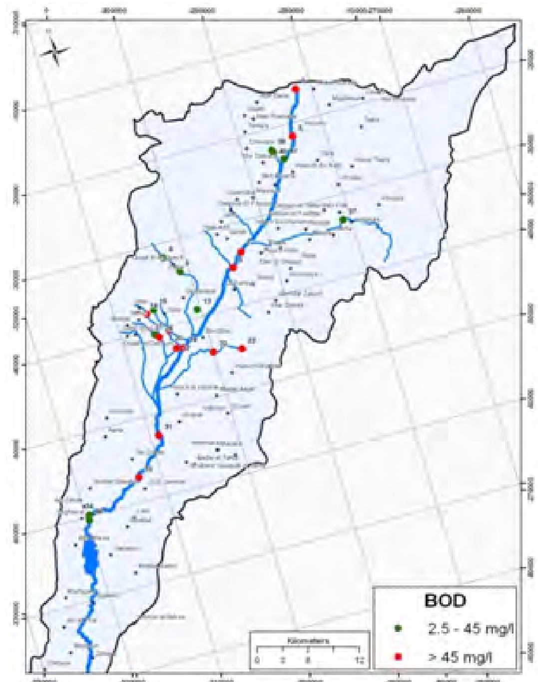


Figure 5: Biological Oxygen Demand along the Litani River and its

Potential water extraction sites are as few due to minimal water flow, high organic loads, high levels of trace metals (mostly cadmium and manganese and to a lesser extent barium) and fecal contamination. Contaminants are mostly attributable to cesspool leachate; sanitary sewer system outlets; leachate of solid waste dump sites; food processing plants (sugar beet, dairy products, fruit jam, juices, vegetable canning) wastewater effluents; industrial zones (dyeing and tanning, electroplating, manufacturing of batteries, chemicals, sponge, paper and stone cutting) wastewater effluents; farm (swine, cows, sheep and poultry) waste, recreational areas sewage discharge and solid waste dumps and agriculture runoff (pesticides and fertilizers). Accordingly, the major identified hot spots are distributed throughout the ULB and are not specific to a single zone but are more evident in:

(a) Hezzine; mainly due to sewage and major municipal solid waste dump site,
(b) Rayak; mainly due to industrial wastewater (e.g. dairy factory Libanlait),
(c) Ferzol; mainly due to industrial wastewater (e.g. Master Potato Chips), disposal of improperly disinfected secondary treated wastewater effluent and solid waste dump by the river,
(d) Ablah; mainly due to industrial wastewater (e.g. Tanmeiyah), domestic wastewater as treatment plant is still under construction and solid waste dump adjacent to the river,
(e) Jdeita; mainly due to industrial wastewater; dairy Plants (e.g. Jarjoura), serum industry and paper mills,
(f) Al Marj; mainly due to municipal solid waste landfill leachate,
(g) Taanayel; mainly due to industrial wastewater (e.g. Taanayel dairy plant),
(h) Ammiq; mainly due to industrial wastewater (e.g. SICOMO industry),
(i) Dier Zanoun; mainly due to domestic wastewater from Anjar & Majd Al Anjar, and
(j) Jeb Janine; mainly due to domestic wastewater from Jeb Janine & Kamed Al Louze as the wastewater treatment plant is still under construction.

In comparison BAMAS 20005 reported the highest levels of contamination within the mid-upper Litani basin, where the largest communities are located and related it mostly to sewage discharge into the river prioir to dilution by the various tributaries.

Additionally, the suitability of river water for irrigation is partially restricted and is associated with:

(a) Increase in soil salinity resulting from increased TDS and BOD levels,
(b) Reduction in water infiltration rates due to increased sodium and manganese levels,
(c) Projected crop toxicity (main element of concern is cadmium as the mean level of 0.0099 mg/l is approaching the maximum recommended level of 0.01 mg/l),
(d) Possible deposition on leaves and fruits associated with increased bicarbonate levels, and

(e) Microbiological safety due to increased total and fecal coliform counts.

Moreover, surface water use by livestock is also restricted by the levels of trace metals.

KEY FINDINGS - LAKE WATER

Comparing the lake water quality profile reported by the BAMAS 2005 to the present study 2010 study, the main findings reflect on: Increase in the overall total dissolved oxygen, masking the increase in biochemical oxygen demand (boosted by organic contaminants), change in pH towards alkalinity reflective mostly of exposure to sewage and industrial wastewater discharge, increased fecal loads (50% of sampled sites), increased levels of cadmium exceeding the recommended Lebanese standard level of 0.005 mg/l by 2 folds with higher levels reported in the mid lake water zone (trace metals were below detectable levels in BAMAS 2005 Study). This change in the water quality profile is concurrent with the progressive exposure to contamination loads from the various identified point and nonpoint sources.

Table: Comparison of Lake Water Quality Profiles Reported by BAMAS Study and Present Study 2010

Indicator	BAMAS (summer) 2005calculated from lake water results			Study (summer) 2010 Lake water results			Drinking water standard	
							MoE-Lebanon	EPA
	Min	Mean	Max	Min	Mean	Max		
Total Dissolved Solids (mg/l)	120	160	196	221	235	256	500	500
pH (pH units)	6.5	7	7.5	8.2	8.27	8.32	6.5-8.5	6.5-8.5
Biochemical Oxygen Demand (mg/l)	<2	2.57	4	2.0	2.65	3.30	NA	NA
Nitrates (mg/l as N)	62	16	21	0.8	0.93	1.20	10	10
Phosphates (mg/l)	0.01	0.13	0.35	0.0	0.09	0.24	NA	NA
Fecal Coliform (CFU/100 ml)	0	17	450	0	160	400	0	0
Cadmium (mg/l)	NA	NA	NA	0.0007	0.010	0.021		0.005

The main findings are:

- Increase in the chemical and biological contamination transferring the better quality middle lake zone (2.5- 3.6 km from the entry point of the river into the lake) into a reducing medium with higher organic loads and more solubility of the metal sediments making the water not suitable for use, and

- Increse in microbiological loads (10 folds) mainly due to discharge of untreated sewage into the lake (sewage treatment plant under construction).

KEY FINDINGS - GROUNDWATER

The overall mean total dissolved solids level is 385 mg/L with maximum level of 863 mg/l and a minimum level of 170 mg/l. This mean level is acceptable when compared to the Lebanese standards (still 12% exceed the standard 500 mg/l level), EPA standards and WHO guidelines recommended levels. All tested macro-elements and microelements fall within the set limit values recommended by these standards and guidelines.

Still, high nitrate levels exceeding the recommended 10 mg/l were detected in 20% of the sampled wells in the areas of Housh Barada, Hezzine, Sariene, Helanieyeh and Ablah. Concurrently, relatively higher chloride (up to 130 mg/l) and sulfate levels (up to 64mg/l) were also detected at these sites. This is mostly associated with the improper management of sewage. Moreover, one sampling site (Ablah) showed high levels of manganese; 2.7 folds standard level. The well water quality at this site should be further investigated to identify the sources of pollution.

Additionally, the presence of fecal coliforms in 16% of samples (in comparison to 35% reported by BAMAS Study 2005).These findings reflect on efforts to increase the coverage of the sanitary sewer systems. This has reduced on the exposure of ground water aquifers to progressive contamination. Yet, at present, the system is still deficient and sewage outfalls continue to discharge along the water flow without any treatment.

Table: Comparison of the **Ground Water** Quality Profile Reported by BAMAS and Present Study 2010

Indicator	BAMAS 2005 Calculated from ground water results			Study 2010 Ground water results			Drinking water standard	
							MoE Lebanon	EPA
	Min	Mean	Max	Min	Mean	Max		
Total Disolved Solids (mg/l)	NA	NA	NA	170	385	863	500	500
pH (pH units)	6.54	6.90	7.22	6.98	7.76	8.72	6.5-8.5	6.5-8.5
Nitrates (mg/l as N)	3	48	171	0.2	6.7	41.0	10	10
Phosphates (mg/l)	0	0.3	12	0.1	1.2	6.43	NA	NA
Fecal Coliform (CFU[11]/100 ml)	0	42.8	400	0	39.2	400	0	0
Manganese mg/l	NA	NA	NA	0.03	0.07	0.54		0.05

The main finding is that water quality improvement remains minimal despite efforts to increase the coverage of the sanitary sewer systems; nitrate levels are still high and need to be addressed.

KEY FINDINGS - SOIL AND SEDIMENT

The survey also investigated the quality of soils and sediments (from the bottom of the river and the lake), which was not previously done under the BAMAS survey. Soil samples represent excellent media to monitor heavy metal pollution as they usually deposit in top soil. Results show the accumulation of the following trace metals in soils and sediments:

Metal	Standards, according to Canadian Trace Metal Guideline Levels for Soils (mg/kg)	% of river sediment samples that exceed standard	% of canal sediment samples that exceed standard
Arsenic	12	84%	92 %
Cadmium	1.4	25 %	25%
Copper	63	25%	25 %
Nickel	50	96%	100 %
Chromium	64	92%	100 %
Mercury	6.6	38%	25%
Manganese	470	67%	86%

This confirms the detection of these trace elements in water samples (surface water, springs, lake and irrigation canal). Although the mobility of trace metals and the uptake by plants is mostly limited by soil alkalinity, yet crop toxicity may result. As such, trace metals are building up due to irrigation with surface and ground water exposed to sewage and industrial wastewater discharge and excessive use of fertilizers and pesticides

Additionally, sediments are sinks for heavy metals entering rivers from anthropogenic sources, such as industrial and municipal wastewater effluents, land-fill leachate, and agriculture runoff. The detection of trace metals (arsenic, nickel, mercury and chromium) in river and lake sediment samples reflects the continuous exposure to pollution. Although it is well known that most potential pollutants in aquatic sediments are nontoxic/non-available forms, changes in ecologic settings and long term exposure may lead to situations where sufficient concentrations of the pollutants are released to the overlying water column and consequently harm aquatic organisms. Aquatic organisms can accumulate these trace elements and become a threat, when consumed, to human health.

CONCLUSION AND RECOMMENDATIONS

The continuous exposure to pollution is disrupting the ecologic balance of the Upper Litani Basin. And the "complete" tapping of Litani springs and tributaries for irrigation is limiting the water flow and thus the ability of the river to restore its oxygen levels through self purification. This is destroying the ability of the ULB to handle increasingly high pollution loads provide acceptable water quality for multiple uses.

Restoring the Litani River and its tributaries ecologic viability cannot be achieved by a single type of environmental intervention and should be part of an Integrated River Basin Management (IRBM) approach, which should include the following short and mid-term measures:

Restore Litani River ecological wellbeing and sustainable water flow by addressing all types of environmental stresses, mobilizing involved communities and empowering municipalities to:

(a) Stop the "complete" tapping of springs and tributaries water flow for irrigation;

(b) Control the drilling of new wells and the overexploitation of ground water aquifers;

(c) Enforce onsite treatment of major industrial wastewater effluents discharging into the Litani River and its tributaries, or into the domestic sewage networks which in turn flow directly into the river;

(d) Prevent the discharge of untreated domestic sewage directly into the river and its tributaries;

(e) Regulate the discharge of municipal and industrial solid wastes along the river water flow;

(f) Raise awareness to reduce the over-application of pesticides.

Protect and sustain the quality of ground water resources; the above recommended interventions will regulate the overexploitation of these resources and reduce the water body exposure to pollution sources. Additionally, the following is recommended:

(a) Enforce existing regulations to replace leaching cesspools with waterproof and properly designed septic tanks;

(b) Regulate the use of fertilizers (types and quantities applied); and

(c) Identify and improve the monitoring of all water sources used by communities, as main and complementary domestic water sources, to determine water safety.

Regulate wastewater use for irrigation; the suitability of raw untreated wastewater for irrigation is depends on wastewater salinity, infiltration rate, plant toxicity and other health factors. If such use is needed due to the scarcity of alternative water supplies, it should be regulated and restricted to crops presenting low risks to consumers.

Enhance the water quality of the Qaraoun Lake; implementing the above interventions will upgrade the water quality of the Qaraoun Lake for various uses; especially irrigation and fisheries. Moreover, treating wastewater effluents along the lake is critical to control the levels of enriching nutrients (mainly phosphates and nitrates) and prevent eutrophication.

Enhance the quality of Irrigation Canal 900; implementing the above interventions will also improve the quality of Canal 900 water since it originates from the lake. Additionally, the levels of added copper sulfate (used to control algae growth) should be monitored to prevent the progressive accumulation of copper in soils irrigated with canal water.

Develop and sustain water quality monitoring programs by:

(a) Initiating ecological studies to identify aquatic biological indicators, monitor the state of aquatic species, and evaluate the need to promote fisheries;

(b) Conducting studies to evaluate the level of the risk associated with the translocation of trace metals into the aerial edible portions of crops grown in soil progressively exposed to wastewater irrigation, and surface and spring water contaminated by sewage and industrial wastewater; and

(c) Conducting studies to evaluate the level of the risk associated with excreta pathogens in fresh water, sewage and on crop surfaces (e.g. *Enteroviruses, Ascaris lambriocoides eggs and Entamoeba histolytica*).

ملخص تنفيذي

تمهيد– موقع الدراسة و اوضاعه

اجريت هذه الدراسة لجزء من عمل "مجموعة الموارد الدولية المحولة من قبل الوكالة الأميريكية للتنمية الدولية في لبنان لمشروع دعم ادارة حوض نهر الليطاني وذلك لمساعدة المصلحة الوطنية لنهر الليطاني في تحسين وتقوية ادارة الحوض الآعلى لنهر الليطاني

وبالتالي فان اهداف الدراسة هي تحديث احصاءات ودراسات توعية المياه التي سنة **2005** ضمن النشاطات التي قام بها برنامج الخدمات الآستشارية لحوض الليطاني الذي مولته آنذاك الوكالة الأميريكية للتنمية الدولية وتتخلص بما يلي :

أ) تقدير وضع نوعية المياه في الحوض الأعلى لنهر الليطاني

ب) مقارنة النتائج الأخيرة بتلك التي حصل عليها سنة **2005** برنامج "باماس" المحول من قبل الوكالة الأميريكية للتنمية الدولية

ج) الأستنتاج من النتائج المذكورة الأخطار الممكنة التي تتأتى من استعمالات المياه المختلفة

د) التوصية بالتدابير المفروض اتخاذها لتحسين الممارسات والسلوك وكذلك اعمال المراقبة لمصادر وانواع التلوث الرئيسية

المسح الميداني الدولي

جرى المسح الميداني والأستكشافي لمدة 16 يوما (من 9 الى 20 تموز 2010)

المنطقة العليا الممتدة من السعيدة الى رياق تمتاز بكونها ذات طابع مختلط بين السكني والزراعي والصناعي. ترقيد النهر واقد اربعة اثنان منها يجفان في فصل الصيف ويبلغ تصريف النهر حده الأدنى لولى مياه الصرف الصحي والمياه المبتذلة الصناعية. اما النفايات الصلبة فالتخلص منها شبه معدوم حيث مكبات النفايات تتوزع عشوائيا على المنطقة. اضافة الى ذلك فان شبكات الصرف الصحي المنزلي والجور الصحية تشكل الطريقة الأساسية للتخلص

النفايات السائلة. هناك محطة معالجة مياه صرفي صحي في الفرزل قيد العمل (معالجة ثانوية/ ميكروبيولوجية) كما ان محطة معالجة اخرى في ابلح هي قيد الأنشاء. اما النشاطات الزراعية فهي زراعة الدخان والقمح والخضار الموسمية. والري يستعمل بشكل كبير مياه الجوفية ومياه المجارير. اما النشاطات الصناعية فهي تتمثل بمعامل الألبان و الكنسروة للمواد الغذائية ومتاشر الصخور والصناعات البلاستكية و الورقية. وتصب النفايات السائلة الصناعية مباشرة في النهر وروافده او في شبكات الصرف الصحي المنزلية التي يتم تصريفها في مجاري المياه السطحية.

المنطقة الوسطى بين رياق وعميق يختلط فيها ايضا الطابع السكني بالطابع الزراعي والصناعي والسياحي وتصريف النهر يتدنى مجددا و يتعرض بشكل كثيف للتلوث الناتج من مياه الصرف الصحي المنزلي والنفايات السائلة الصناعية. يغلب على المياه اللون الأخضر الناتج عن النمو الكبير للطحالب. وبالرغم من ان النهر يتلقى مياه روافد خمسة فهو في الصيف جاف او سحبت مياهه للري.

وهناك مطمر للنفايات الصلبة في زحلة انما المكبات المفتوحة ما زالت تستعمل في الكثير من البلدات / القرى. اما ادارة المياه المبتذلة المنزلية و شبكات الصرف الصحي (في اكثرها) و الجور الصحية (قليلا) فهي الطرق الأساسية للتخلص منها علما انه يجري حاليا بناء محطة معالجة مياه الصرف الصحي (معالجة ثانوية/ بيولوجية) مركزها بين حوش الأمراء وبر الياس. وتعود أكثر النشاطات الزراعية الى زراعة الخضار الموسمية مع اعتماد اساسي على مياه المجارير لريها. كما ان هذه المنطقة تمتاز بكونها ذات طابع صناعي ناشط: معامل البان واجبان و منتجات غذائية تعبئة المياه في القناني و النبيذ والورق والصباغات والدباغات وصناعة البطاريات وتعليب المواد الغذائية الخ ... ولا تزال المياه المبتذلة الصناعية تصرف مباشرة في النهر او في المجارير البلدية التي تصب في النهر علما ان هذه المنطقة معروفة بمطاعمها وفنادقها خاصة في زحلة شتورا و عنجر.

اما المنطقة الدنيا فهي تمتد من عميق حتى القرعون وهي ايضا مزيجا من مناطق سكنية وزراعية و بنسبة أقل صناعية و ترفيهية و تربية نباتات مائية. ويبدأ النهر بتخفيف الدفق الى حده الأدنى مما يؤدي الى نمو الطحالب بشكل كبير وتواجد بعض الأسماك والثعابين المائية والسلاحف و البط و الخ... اما الروافد فهي شبه جافة بالكامل في خلال فصل الصيف او ان مياهها قد حولت لأغراض الري. ثم يسيل النهر نحو بحيرة القرعون بتصريف مائي أكبر نسبيا

بفضل ينابيع تعيد مياها سبق أن تسربت طوال المسار السابق للنهر الى جوف الأرض اضافة الى تصريف مياه الصرف الصحي المنزلية و مياه الرجع الزراعي. فضلا عن ادارة النفايات الصلبة البلدية غير كافية ويتم التخلص من مياه الصرف الصحي من خلال جور صحية. وهناك حاليا محطة معالجة مياه مبتذلة هامة قيد الأنشاء في جب جنين اما النشاطات الزراعية وهي تعود لزراعة الكرمة في معظمها والأراضي الزراعية تعتمد في غالبيتها على القناة 900 التي تأخذ مياهها من بحيرة القرعون وتجرها عبر القرى المجاورة. فميا يعود للنشاطات الصناعية فهي ضئيلة في المنطقة و تتضمن صناعة السكر و ورشات اصلاح السيارات والصناعات الورقية والصياغات والدباغات. ويجري التخلص من النفايات السائلة الصناعية في النهر اما مباشرة واما من خلال شبكات الصرف الصحي المنزلية التي تصب في النهاية في النهر.

المنهجية

في خلال هذه الدراسة جمعت (149) فقط ماية و تسع واربعون عينة في فترة (22) اثنين وعشرون يوما (اب – ايلول 2010) من:

أ) من ننهر الليطاني وروافده (26)

ب) من بحيرة القرعون (10)

ج) من القناة 900 للري (7)

د) من المياه الجوفية (ابار و ينابيع) الواقعة ضمن الحوض الأعلى لنهر الليطاني (42)

ه) من مياه الصرف الصحي المنزلي للمناطق السكنية الواقعة على ضفات النهر (12)

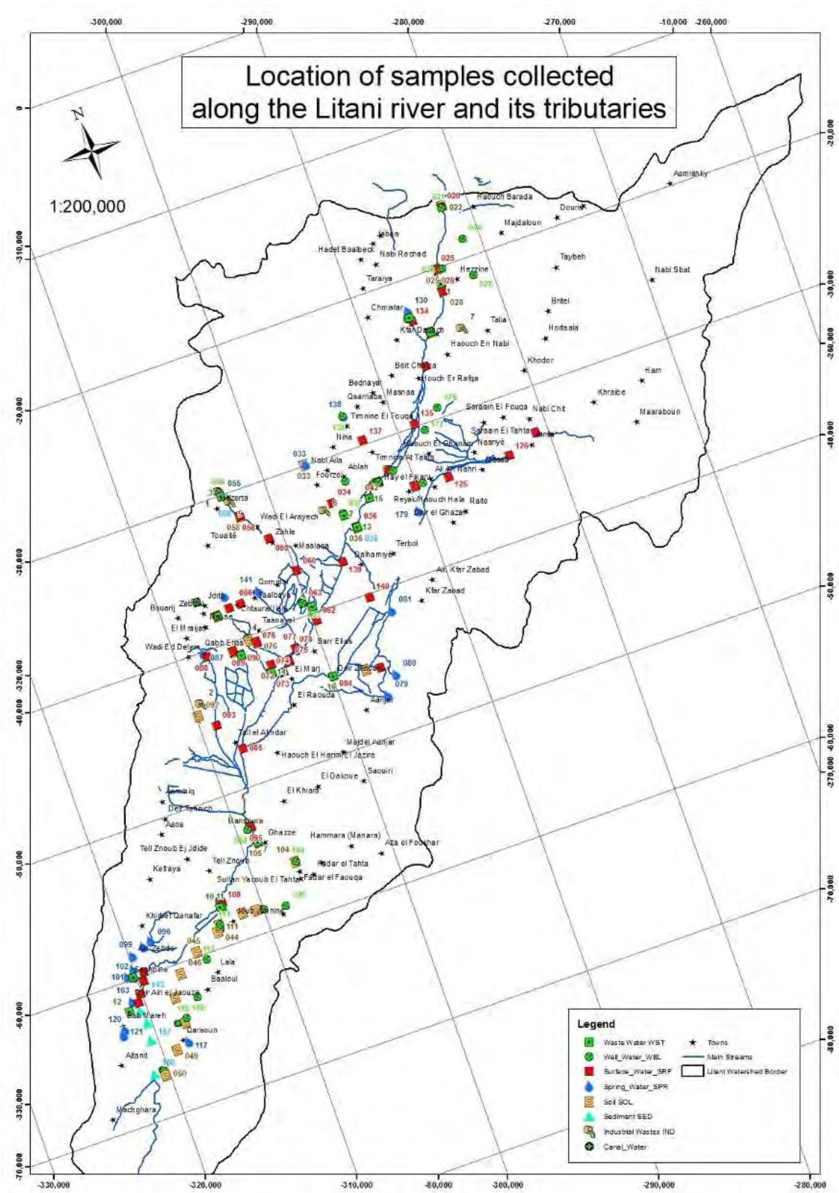
و) من المياه المتذ لة الصناعية التي تصب مباشرة في النهر (7)

ز) من التربة الزراعية للمناطق التي تقع على ضفات النهر وقناة الري (26)

ح) مت ترسبات السطحي في النهر والبحيرة (8)

ويبين المصور (رقم ا) المرفق انواع ومواقع العينات وقد جمعت العينات ونقلت وتم تحليلها وفقا للمعا يير العالمية طرقا ومنهجا.

وتم الحصول على نتائج فيزيائية كاملة وكيميائية وميكروبيولوجية (كامل الموارد الصلبة الذائبة و الأيصالية الكهربائية و الأوكسيجان الذائب والطلب البيوكيميائي للأوكسيجان والحموضة والقلوية والأمونيا والنيترات والكلسيوم والماغنيزيوم والصوديوم و الرصاص و الزئبق و الكادميوم و الكرومو النيكل و النحاسو الزنك والحديد والباريوم والكوبالت والكروم والنيكل والنحاس والزنك والحديد والباريوم والكوبالت والبورون والمانغانيز والموليبدات والكلورينات العضوية و المواد العضوية الفوسفورية ومجموع الكوليفورم والكوليفورم البرازي والستريبتوكوك البرازي اضافة الى ذلك تم مقارنة التحاليل مع بيانات 2005 لمشروع "باماس" لتبين ما اذا كانت هناك تغييرات في نوعية المياه مع الزمن.



موقع العينات التي تجميعها على طول مجرى نهر الليطاني و روافده.

النتائج الرئيسية التي تم الحصول عليها – المياه السطحية

تبين النتائج(انظر اللا ئحة ادناه) تدنيا ملموسا في نوعية النهر مقارنة مع نتائج "باماس" 2005 وهذا واضح:

. ارتفاع في التلوث البيولوجي (ارتفاع عشرة اضعاف في الطلب البيولوجي على اللأوكسيجين) ناتج عن صب مياه الصرف الصحي غير المعالجة وعصارة مطامر النفايات الصلبة المنزلية يضاف اليها صب المياه المبتذلة الصناعية غير المعالجة جميعها في النهر وروافده.

. ارتفاع في التلوث البيولوجي (170% زيادة في المواد الصلبة الذائبة و تحول الحموضة نحو القلوية) وهي تعكس في الغالب التعرض الدائم للمياه المبتذلة المنزلية والصناعية بالرغم من الجهود لزيادة التغطية بانظمة الصرف الصحي.

. تخفييض نسبة الملوثات الميكروبيولوجية بالرغم من التعرض المستمر للمياه المبتذلة خاصة لكون مستويات الأوكسيجين متدنية جدا فيها والتصريف المائي يتضائل وكون المياه معرضة طويلا لأشعة الشمس فوق البنفسجية.

لائحة مقارنة بين عناصر نوعية المياه السطحية التي سجلتها"باماس" والدراسة الحالية 2010

المعايير القياسية لمياه	دراسة صيف 2010 نتائج المياه	باماس صيف 2005 المحسوبة من نتائج	المؤشر

	المياه السطحية			السطحية			الشرب	
							وزارة الطاقة و المياه	وكالة حماية البيئة
	الأدنى	المعدل	الأعلى	الأدنى	المعدل	الأعلى	25^0C	
[1]مجموع المواد الصلبة الذائبة (ملغم/ليتر)	88	290.96	706	187	502	1979	<500[8]	<500
[2] الحموضة (وحدة الحموضة)	6.57	7.09	7.68	7.27	7.93	8.66	6.5-8.5	6.5-8.5
[3] الطلب البيوكيميائي للأوكسيجين (ملغم/ليتر)	2	48.46	624	2.50	547	2530	NA	NA
[4] نيترات (ملغم/ ليتر)	3	13.46	62	0.10	1.23	4.90	<10	<10
فوسفات (ماغم/ ليتر)	0	11.75	197	0.00	8.58	72	NA*	NA
[5] كوليفورم برازي	0	223,487	150,000	1	71.61	400	0	0
[6] كادميوم (ملغم/ ليتر)	NA	NA	NA	0.00 5	O.01	0.079		<0.005
[6] مانغنيز (ماغم/ ليتر)	NA	NA	NA	0.01	0.07	0.27		<0.05

NA لا يطبق

تعريف المؤشرات:

1- مجموع المواد الصلبة الذائبة : قياسات المحتويات المعدنية وهي تعكس نوعية منبع المياه و تعرضها للتلوث. و ارتفاع مستوى التلوث في المياه السطحية يمثل غالبا تعرض المياه المتزايد لمياه الصرف الصحي المنزلية و الصناعية و عصارة مطامر النفايات الصلبة المنزلية و كذلك رجع المياه الزراعية.

2- الحموضة : تقيس او القلوية و مياه الرجع الزراعي و الصرف الصحي تدفع بالحموضة نحو القلوية.

3- الطلب البيولوجي للأ وكسيجين : يقيس كمية الأو كسيجين اللازمة للكائنات الحية المتنهية الصغر الهوائية لمعالجة التلوث العضوي و ارتفاع نسبة الطلب البيولوجي للأ وكسيجين تبين تلوثا ناتجا عن مياه الصرف الصحي و معالجة غير فعالة للمياه المبتذلة و المياه الناتجة عن معامل الكونسروة الزراعية و الأستعمال المفرط للمخصبات العضوية.

4- النيترات : يقيس نسبة النيترات التي تسبب نمو الطحالب و تؤثر عليها. اما مصادر النيترات فهي مشتتة من رجع المياه الزراعية من الأراضي التي سمدت بافراط و ارتفاع نسبة النبترات غير مناسب للأستعمال المنزلي.

5- الكوليفورم البرازي : يقيس كمية المياه المبتذلة التي تصب و ان المستويات المنخفضة التي تبينت في خلال المسح الأحصاء (مقارنة مع ارقام "باماس") ناتجة عن ظروف غير مؤاتية لتنمية الكائنات الحية في البراز و ليس عن انخفاض كمية مياه الصرف الصحي.

6- الكادميوم و الماغنيزيوم : مؤشرات المعادن الثقيلة التي تقيس التعرض لمياه الرجع الزراعي (الأستعمال المفرط للمبيدات و المخصبات).

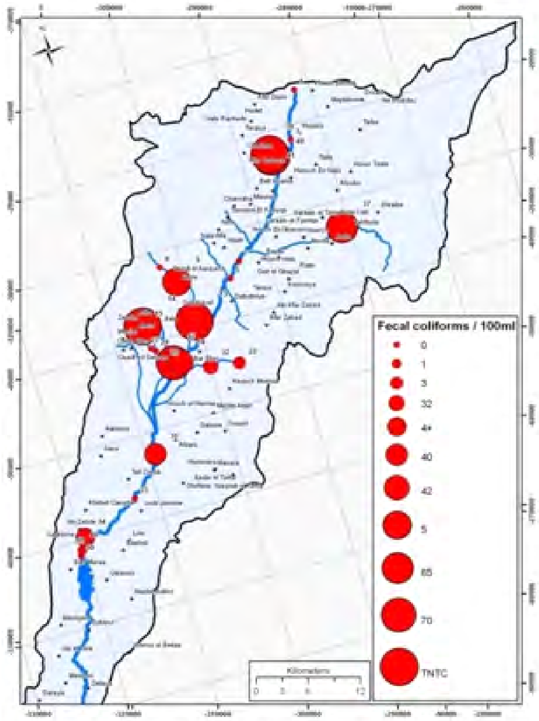


Figure1: Feacal Coliforms Along the Litani River and its Tributaries

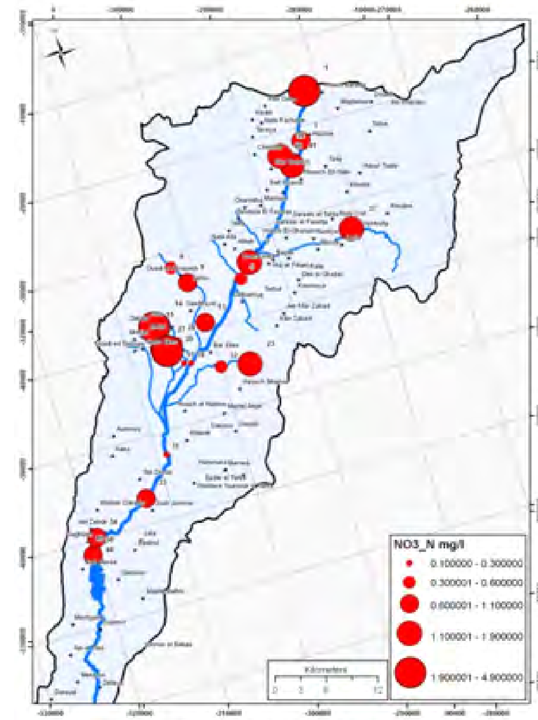


Figure 2: Nitrates Levels Along the Litani River and its Tributaries

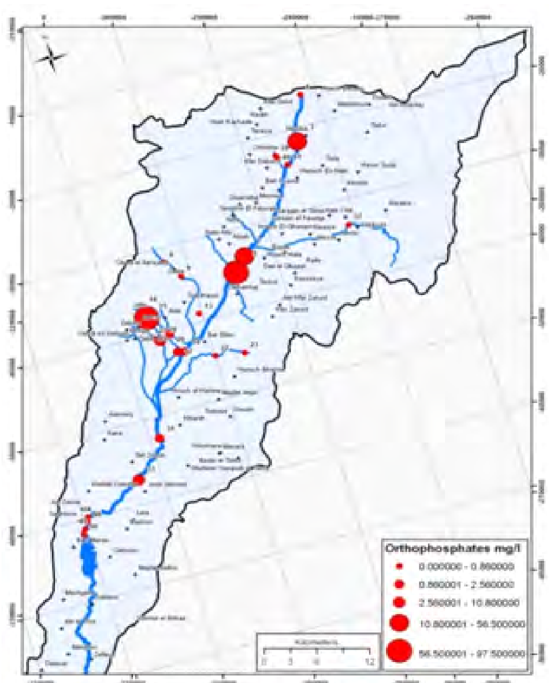


Figure 4: Phosphates Levels along the Litani River and its Tributaries

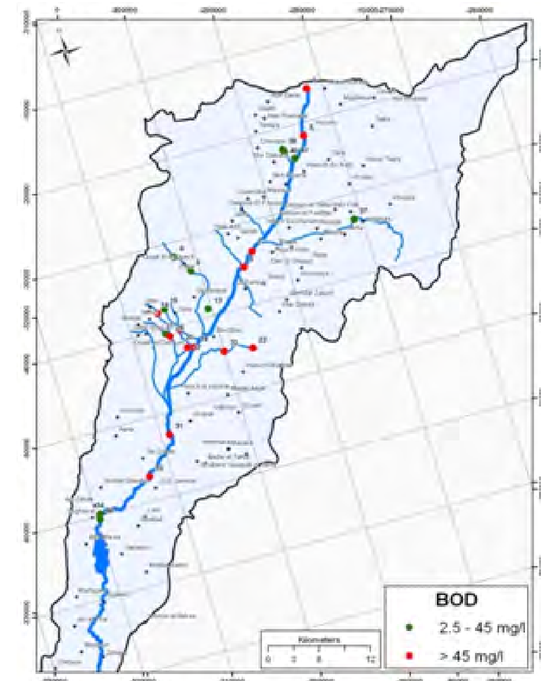


Figure 5: Biological Oxygen Demand along the Litani River and its

تعتبر المواقع الأفتراضية لسحب المياه قليلة نسبيا بسبب ضالة تصريف المياه وارتفاع الملوثات العضوية وعلى مستويات المعادن الثقيلة (ومعظمها الكادميوم و المانغنيز وبنسبة اقل الباريوم) والملوثات البلرازية.

الملوثات تنتج غالبا عن الجور التي تصب فيها المياه المبتذلة و عن مخارج انظمة مجاري الصرف الصحي وعصارات مطامر النفايات الصلبة وعن المياه المبتذلة الصناعية الناتجة عن معامل المواد الغذائية (الشمندر السكري و الألبان و الأجبان و المربيات و عصير الفواكه و الكوستروة الخضار) وعن المناطق الصناعية (الصباغات و الدباغة و التلبيس المعدني الكهربائي و صناعة البطاريات و الكيمياويات والأسفنج والورق ومناشر الصخر) وعن المزارع (تربية الخنازير و البقر و الغنم و الدجاج) وعن نفايات المناطق السياحية السائلة والصلبة ومطامر النفايات الصلبة ومياه الرجع الزراعي (مبيدات و مخصبات) وبناء عليه فان المناطق التي تعتبر نقاط خطرة موزعة على كامل منطقة الحوض اللاعلى لنهر الليطاني وليست حكرا على منطقة وحيدة لكنها تبرز أكثر في:

أ) جزين : بسبب مياه الصرف الصحي المنزلية وموقع مطمر النفايات الصلبة البلدية

ب) رياق : بسبب المياه المبتذلة الصناعية (مصنع البان لبان لي)

ج) الفرزل : بسبب المياه المتذلة الصناعية (مصنع لبطاطا المقلية " ماستر بوتاتو شيبس") وبسبب التخلص من مياه الصرف الصحي المعالجة المعقمة للمستوى الثانوي بشكل غير مناسب وكذلك من النفايات الصلبة في النهر.

د) ابلح: بسبب المياه المبتذلة الصناعية (التحتية) ومياه الصرف الصحي المنزلية حيث محطة المعالجة لا تزال قيد الانشاء و بسبب النفايات الصلبة المحادثة للنهر

ه) حديتا : بسبب المياه المبتذلة الصناعية كمصانع الألبان و الأجبان (جرجورة) وصناعة الامصال والورق.

و) المرج : بسبب عصارة مكبات النفايات الصلب والبلدية

ز) تعنايل : بسبب المياه المبتذلة الصناعية (معمل البان و اجبان تعنايل)

ح) دير زنون : بسبب مياه الصرف الصحي المنزلية اللآتية من عنجر ومجدل عنجر

ط) جب جنين : بسبب الصرف الصحي المنزلية الآتية من جب جنين و كامد اللوز حيث لا تزال محطة معالجة المياه المبتذلة قيد الأنشاء حاليا.

وبالمقارنة بتقرير "باماس" سنة 2005 يبين ان على مستويات التلوث تقع في اوساط الحوض الأعلى لنهر الليطاني حيث توجد التجمعات السكنية الكبرى وتتأتى بمعظمها من مكبات مياه الصرف الصحي في النهر قبل ان ترفده مياه الأنهر الرواقد المختلفة.

اضافة الى ما تقدم فان مياه النهر و مناسبتها للري محددة جزئيا و يرافقها:

أ) ازدياد ملوحة التربة الناتجة عن ارتفاع مستوى مجموع الموارد الصلبة المذابة والطلب البيولوجي على الأوكسيجين

ب) انخفاض نسب تسرب المياه بسبب ارتفاع نسبة الصوديوم والمانغنيز

ج) تسمم المنتجات الزراعية المرتفعة (والعنصر الأكثر خطرا هو الكاديوم حين يباغ المستوى 0.0099 ملغم / ليتر و يقترب من الحد الأقصى المقبول و هو 0.01 ملغم/ ليتر)

د) امكانية تغطية الأوراق والثمار تترافق مع ارتفاع مستوى البيكاربونات

ه) تهديد السلامة البيولوجية بسبب زيادة اعداد الكوليفورم البيولوجي والبرازي.

اضافة الى ما تقدم فان استعمال الحيوانات الأليفة للمياه يحدد وفقا لمستويات المعادن الثقيلة الموجودة.

النتائج الأساسية- مياه البحيرة

بمقارنة ميزات نوعية مياه البحيرة المسجلة في تقرر " باماس" 2005 مع الدراسة الحالية لسنة 2010 فان النتائج تبين : زيادة في مجمل الأوكسيجين المذاب مما ادى الى زيادة الطلب البيوكيميائي للأوكسيجين (الذي زادته الملونات

العضوية) وبالتالي الى تحويل الحموضة نحو القلوية بسبب تعرض المياه غالبا للمياه المبتذلة المنزلية والصناعية و لمكونات برازية متزايدة (50% من مواقع الأعتيان) ولمستويات متزايدة من الكادميوم التي تتعدى المستويات القياسية المعتمدة من قبل الأنظمة اللبنانية و البالغة 0.005 ماغم/ليتر بضعفين مع مستويات اعلى في المنطقة الوسطى من البحيرة (نسبة المعادن الثقيلة كانت أقل من المستويات الممكن كشفها وفقا لدراسة "باماس" 2005) ويرافق هذا التغيير في نوعية المياه مع تعرضها المتزايد للملونات من النقاط المعينة المختلفة ومن المصادر الموزعة على مساحة الحوض.

لائحة مقارنة عناصر نوعية المياه بين دراسة باماس و الدراسة الحالية 2010

المؤشر	"باماس" صيف 2005 المحتسبة من نتائج مياه البحيرة			الدراسة الحالية صيف 2010 نتائج مياه البحيرة			معايير مياه الشرب	
							وزارة الطاقة و المياه	وكالة حماية البيئة
	الأدنى	المعدل	الأعلى	الأدنى	المعدل	الأعلى		
كامل المواد الصلبة المذابة ملغم/ليتر	120	160	196	221	235	256	500	500
الحموضة (وحدة الحموضة)	6.5	7	7.5	8.2	8.27	8.32	6.5-8.5	6.5-8.5
الطلب البيوكيميائي للأوكسيجين (ملغم/ليتر)	<2	2.57	4	2.0	2.65	3.30	NA	NA
النيترات (ملغم/ليتر)	62	16	21	0.8	0.93	1.20	10	10
الفوسفات (ملغم/ليتر)	0.01	0.13	0.35	0.0	0.09	0.24	NA	NA
الكوليفورم البرازي ***(CFU/100ml)***	0	17	450	0	160	400	0	0
الكادميوم (ملغم/ليتر)	NA	NA	NA	0.0007	0.010	0.021		0.005

وفي ما يلي أهم النتائج :

. ازدياد في نسبة التلوث الكيميائي والبيولوجي مما نقل النوعية الحسنى لمياه اواسط البحيرة (2.5 الى 3.6 كم من نقطة دخول النهر الى البحيرة) الى وسط مقلص مع زيادة في الملوثات العضوية وزيادة ذوبان الترسبات المعدنية مما يجعل المياه غير مناسبة للأستعمال.

. زيادة في الملوثات الميكروبيولوجية (عشر أضعاف) الناتجة من صب مياه الصرف الصحي غير المعالجة في البحيرة (محطة معالجة المياه المبتذلة قيد الانشاء).

النتائج الأساسية – المياه الجوفية

يبلغ مستوى المواد الصلبة المذابة اجمالا ما معدله 285 ملغم/ليتر مع مستوى أقصى بلغ 863 ملغم/ليتر ومستوى أدنى بلغ 170 ملغم/ليتر. وهذا المعدل يعتبر مقبولا اذا ما قورن مع المعايير اللبنانية (و هي تفوق ب 120 % معيار 500 ملغم/ ليتر) المستويات الموصى بها من قبل تعليمات منظمة الصحة العالمية ومعايير وكالة حماية البيئة (الأميريكية). علما ان كافة العينات للعناصر الكبرى والصغرى تقع ضمن الحدود التي توصى بها المعايير والتعليمات.

وكذلك تبين ان مستوى النيترات التي تفوق ال 10 ملغم/ليتر الموصى بها قد وجدت في 20% من الآبار التي تم اعتيانها في محيط حوش بردي وجزين وسرعين والحلانية وابلح. وقد وجدت ايضا مستويات عاليا من الكلورايد (حتى 120 ملغم/ ليتر) وسلفات (حتى 64 ملغم/ليتر) في المواقع ذاتها. ويرافق هذا الواقع ادارة غير مناسبة لمياه الصرف الصحي. بالاضافة الى ما تقدم فقد أظهر احد مواقع الاعتيان (ابلح) مستويات عالية من المانغنيز 2.7 ضعف المعيار المعتمد للمستوى ومن الضروري العمل على اجراء المزيد من الابحاث على نوعية مياه البئر في الموقع المذكور لتحديد مصادر التلوث اضف الى ذلك تبين وجود الكوليفورم البرازي في 16% من العينات(مقارنة مع 25% الواردة في تقرير "باماس" 2005). هذه النتائج تعكس الجهود التي بذلت لزيادة التغطية بانظمة جمع مياه الصرف الصحي.

وقد خفضت هذه التدابير تعرض الطبقات الجوفية للمزيد من الملوثات. انما . يزال هذا النظام خفيفا و لا تزال مياه الصرف الصحي المنزلي يصب على طول مجرى النهر دون أي معالجة.

لائحة مقارنة المياه الجوفية بين " باماس " و الدراسة الحالية 2010

معايير مياه الشرب		الدراسة الحالية صيف 2010 نتائج مياه البحيرة			"باماس" صيف 2005 المحتسبة من نتائج مياه البحيرة			المؤشر
وكالة حماية البيئة	وزارة الطاقة و المياه							
		الأعلى	المعدل	الأدنى	الأعلى	المعدل	الأدنى	
500	500	863	385	170	NA	NA	NA	كامل المواد الصلبة الذائبة (ملغم/ليتر)
6.5-8.5	6.5-8.5	8.72	7.76	6.98	7.22	6.90	6.54	الحموضة (وحدة الحموضة)
10	10	41.0	6.7	0.2	171	48	3	النيترات (ماغم/ ليتر)
NA	NA	6.43	1.2	0.1	12	0.3	0	الفوسفات (ماغم / ليتر)
0	0	400	39.2	0	400	42.8	0	الكوليفورم البرازي ***(CFU/100 ml)***
0.05		0.54	0.07	0.03	NA	NA	NA	الماغنيزيوم (ملغم/ ليتر)

ان النتائج الرئيسية تبين أن تحسن نوعية المياه تبقى متدنية بالرغم من الجهود لزيادة تغطية مياه الصرف الصحي للمناطق ولا تزال مستويات النيترات عالية وتحتاج لمن يهتم بمعالجتها.

النتائج الرئيسية- التربة و الترسبات

تجرى المسح نوعية التربة والترسبات (من قعر النهر و البحيرة) التي لم تقم به سابقا " باماس" في مسحها السابق. وتمثل عينات التربة وسيلة ممتازة لمتابعة التلوث بالمعادن الثقيلة حيث تترسب فوق الطبقة العليا من التربة. وأظهرت النتائج تجمع المعادن الثقيلة التالية في التربة والترسبات.

المعادن	المعيير وفقا للتعليمات الكندية العائدة للمعادن الثقيلة في التربة (ملغم/ليتر)	نسبة مؤية من عينات ترسبات النهر التي تتعدى المعايير المعتمدة	نسبة مؤية من عينات ترسبات القناة التي تتعدى المعايير المعتمدة
الزرنيخ	12	84%	92 %
الكادميوم	1.4	25 %	25%
النحاس	63	25%	25 %
النيكل	50	96%	100 %
الكروم	64	92%	100 %
الزئبق	6.6	38%	25%
المانغنيز	470	67%	86%

ويؤكد هذا كشف وجود اثار المعادن الثقيلة في عينات المياه (المياه السطحية و الينابيع و البحيرة و قناة الري) انما سرعة حركة المعادن الثقيلة وتأثر النباتات بها محددة غالبا بقلوية التربة لكي يمكن حصول تسمما في المنتجات الزراعية. و لذلك يستعجل وجود المعادن الثقيلة بسبب الري بالمياه السطحية والجوفية المعرضة لمياه الصرف الصحي المنزلية و المياه المبتذلة الصناعية والاستعمال المفرط للمخصبات والمبيدات.

بالاضافة فان الترسبات تجمع المعادن الثقيلة التي تدخل النهر بفعل نشاطات السكان كالمياه المبتذلة البلدية والصناعية وعصارات مطامر النفايات الصلبة ومياه الرجع الزراعي. وكشف المعادن الثقيلة (زرنيخ ونيكل وزئبق و كروم) في عينات ترسبات النهر و البحيرة يعكس تعرض المياه المستمر للتلوث. بالرغم من انه من المعروف ان اكثر الملوثات المفترضة في الترسبات المائية هي اشكال غير سامة / غير ممكن الحصول عليها والتغيرات في الترتيبات الايكولوجية وتعرض المياه المستمر لمدة طويلة تؤدي الى أوضاع حيث الملوثات المركزة بشكل كاف تغطي الطبقات العليا من المياه و بالتالي تلحق الضرر بالكائنات الحية المائية. ويمكن للكائنات المائية أن تجمع عناصر المعادن الثقيلة وأن تغدو خطرا على صحة الانسان عند استهلاكها.

الخلاصة و التوصيات

أن تعرض المياه المستمر للتلوث يؤثر سلبا على التوازن الايكولوجي في الحوض الأعلى لنهر الليطاني. والسخب الكامل لمياه ينابيع الليطاني وروافده لأغراض الري تحد من دفق المياه وبالتالي امكان النهر من استعادة مستويات

الأوكسيجين فيه من خلال التقنية الذاتية. وهذا ما يدمر امكان الحوض الأعلى لنهر الليطاني من معالجة ارتفاع التلوث المتزايد وكذلك تأمين نوعية مياه مقبولة ومناسبة لمختلف الاستعمالات.

ولا يمكن استعادة الاستدامة البيولوجية لنهر الليطاني و روافده بواسطة نوع واحد من التدخل البيئي ويقتضي ذلك أن يكون جزءا من الادارة المتكاملة لحوض النهر التي عليها أن تتضمن التدابير التالية على المديين القصير والمتوسط.

اعادة رفاهية نهر الليطاني الايكولوجية وتصريف المياه المستدام بمعالجة كافة انواع الضغوطات البيئية بتحريك التجمعات السكنية المعنية واعطاء الصلحيات للبلديات كي:

أ) توقف السحب الكامل للمياه لأغراض الري من الينابيع وروافد الليطاني

ب) المراقبة والتحكم بحفر الآبار الجديدة و الأستنزاف الجائر لطبقات المياه الجوفية

ج) اجبار المصانع على معالجة مياهها المبتذلة التي تصب مباشرة في الليطاني وروافده أو في شبكات مياه الصرف الصحي التي تصب بدورها مباشرة في النهر

د) منع مياه الصرف الصحي غير المعالجة من أن تصب بدورها مباشرة في النهر وروافده

ه) منع التخلص من النفايات الصلبة البلدية والصناعية في مياه النهر

و) القيام بحملات توعية وترشيد لتخفيف من الأستعمال المفرط للمبيدات

حماية نوعية الموارد المائية الجوفية و الحفاظ عليها ستنظم التدابير المذكورة أعلاه الأستنذاف الجائر لهذه الموارد وتخفض تعرض المياه للتلوث بالاضافة يوصى بما يلي:

أ) تطبيق الأنظمة الحالية للجور التي تكب فيها الوحول وعصارات النفايات السائلة والصلبة واستبدالها بجور صحية كاتمة ومصممة وفقا للأوصول

ب) تنظيم استعمال الأسمدة المخصبة (النوعيات ة الكميات المستعملة)

ج) تحديد مصادر المياه كافة والمستعملة من قبل التجمعات السكنيية وتحسين مراقبتها حين تستعمل هذه المصادر كمصادر أساسية أو ثانوية للمياه المنزلية وذلك حفاظا على سلامة المياه

تنظيم استعمال المياه المبتذلة للري : ان استعمال المياه المبتذلة غير المعالجة يمكن تحديد ما اذا كانت مناسبة ام لا لأغراض الري حسب ملوحة المياه المبتذلة ونسبة تسربها الى جوف الأرض وسحبة النباتات وغير من العوامل الصحية. وفي حال ضرورة استعمال هكذا مياه بسبب صعوبة ايجاد مصادر مياه بديلة فيجب تنظيمها واقتصادها على المنتجات الزراعية التي تمثل اخطارا دنيا على المستهلكين.

تحسين نوعية مياه بحيرة القرعون ان تنفيذ التدابير المذكورة اعلاه سيحسن نوعية مياه بحيرة القرعون للاستعمالات المختلفة خاصة للري وتربية الأسماك انما معالجة المياه المبتذلة على ضفاف البحيرة تعتبر أساسية لمراقبة مستويات المواد المغذية (في معظمها فوسفات ونيترات) وتمنع انعدام الأوكسيجين في الماء (المياه الميتة)

تحسين نوعية مياه القناة 900 للري سيساعد تنفيذ التدابير المذكورة اعلاه بتحسين نوعية مياه القناة 900 بما انها تأخذ مياهها من البحيرة. بالاضافة فان من الضروري مراقبة مستويات سلفات النحاس المضافة (المستعملة لمحاربة نمو الطحالب) لمنع تجمع النحاس في التربة التي ترويها مياه القناة.

وضع ومتابعة برامج مراقبة نوعية المياه وذلك:

أ) بالمباشرة بدراسات ايكولوجية لتحديد مؤشرات بيولوجية مائية و مابعة اوضاع انواع الكائنات الحية المائية و تقييم الحاجة لتشجيع تربية الأسماك

ب) باجراء دراسات لتقدير مستوى الأخطار المرافقة لانتقال المعادن الثقيلة الى الأجزاء التي يتم استهلاكها من المنتجات الزراعية التي تنمو في تربة معرضة تدريجيا للري بالمياه المبتذلة والمياه السطحية و الينابيع الملوثة بمياه الصرف الصحي المنزلي والمياه المبتذلة الصناعية.

ج) اجراء دراسات لتقدير الأخطار المرافقة لتعرض المياه العذبة للجراثيم البرازية والمياه المبتذلة وعلى سطح المنتجات الزراعية

(e.g. *Enteroviruses, Ascaris lambriocoides eggs and Entamoeba histolytica*).

1. INTRODUCTION

1.1. AUTHORIZATION

International Resources Group (IRG) was contracted by USAID/Lebanon (Contract EPP-I-00-04-00024-00 Task Order No. 7) under the Integrated Water and Coastal Resources Management Indefinite Quantity Contract (IQC) II to implement the Litani River Basin Management Support (LRBMS) Program. The period of performance of the contract is September 29, 2009 to September 30, 2012.

1.2. PURPOSE OF THIS REPORT

The purpose of this report is to present the results of a Litani River Basin-wide survey that was carried out in Summer-Fall 2010 to investigate the quality of surface, spring, canal and ground-waters. This survey was conducted by a team from the American University of Beirut (AUB) led by Dr. Mey Jurdi (Professor and Chair, Environmental Health Department) and including:

- Dr. Samira Korfali (Project Consultant, Lebanese American University)
- Ms. Mona El Rez (Field Work Coordinator)
- Ms. Nora Karahagopian (Technical Lab Supervisor, AUB)
- Mr. Khalil Kreidieh (Research Assistant, AUB)

1.3. PROGRAM OBJECTIVES

The purpose of the LRBMS Program is to set the ground for improved, more efficient and sustainable basin management at the Litani river basin through provision of technical support to the Litani River Authority and implementation of limited small scale infrastructure activities.

The LRBMS program is part of USAID's increasing support to the water sector in Lebanon. The Litani River Basin suffers the fate of many river basins around the world: increasing demands compete for limited natural resources. Groundwater over-exploitation, deforestation and overgrazing, unplanned urban sprawl, untreated wastewater effluents, and unsustainable agricultural practices contribute to environmental degradation in the form of declining water and soil quality.

Solutions do exist to reverse these trends and establish sustainable management practices. The key to successfully implementing such solutions requires applying the principles of Integrated Water Resources Management (IWRM) through a single river basin authority rather than multiple agencies responsible for different aspects of water management as is the case in many countries. Fortunately, the existence of the

Litani River Authority (LRA) provides a unique platform to become such an IWRM river basin authority that will mobilize stakeholders in the river basin and address these challenges in an integrated manner. Successful implementation of LRBMS will prepare the LRA to assume the role of an integrated river basin authority when legal constraints are removed.

1.4. PROGRAM COMPONENTS

Under the LRBMS program, LRBMS will work with national and regional institutions and stakeholders to set the ground for improved, more efficient and sustainable basin management at the Litani River basin. The LRBMS technical assistance team will provide technical services and related resources to LRA in order to improve their planning and operational performance and equip them with the necessary resources for improved river basin management.

To achieve the LRBMS program objectives, the Contractor shall undertake tasks grouped under the following four components:

1) Building Capacity of LRA towards Integrated River Basin Management
2) Long Term Water Monitoring of the Litani River
3) Integrated Irrigation Management which will be implemented under two sub-components:
    a. Participatory Agriculture Extension Program: implemented under a Pilot Area: West Bekaa Irrigation Management Project
    b. Machghara Plain Irrigation Plan
4) Risk Management which will be implemented under two sub-components:
    a. Qaraoun Dam Monitoring System
    b. Litani River Flood Management Model

2. BACKGROUND INFORMATION

The Litani River is the largest and most important water resource in Lebanon. The river is 170 km in length with 60 km of tributaries, draining over 2170 km^2 (20% of the countries area) and totally contained within its boundaries. The river arises from Nabeh Al Oleik near Baalbek and flows into the Mediterranean 70 km south of Beirut (7 km north of Tyre).

Attempts to tap this potential water resource lead to the establishment of the Litani River Authority (LRA) on August 12, 1954. The main tasks of LRA were to (a) implement the "Litani River Master Plan" for irrigation, drainage and domestic water, and execute the hydroelectric system based on tapping the 800-m head between the river site at Qaraoun and the Mediterranean (Sleiman nd; Assaf and Saadeh 2008). This entailed the construction of Qaraoun dam and the diversion of the Litani river through a "system of tunnels and ponds" to empty its flow at a point north from its natural mouth (Assaf and Saadeh 2008; LRA, 2004). This act resulted in hydrological separation between the upper Litani basin (ULB) above the Qaraoun Lake, and the lower reaches (Assaf and Saadeh 2008).

Still, the implementation of the watershed management plans and the water supply schemes (irrigation and domestic) continue to be challenged by prolonged social and economical instability in the country. The Litani River Authority attempting to cope with the increased water demands constructed Irrigation Canal 900 that diverts a total 150 MCM of water per year from the Qaraoun Lake for irrigation. Another major project to be implemented is the construction of Irrigation Canal 800 that will provide an additional 110 MCM of water per year to respond to the escalating irrigation water demands in the Bekaa and South Lebanon. Nevertheless, and despite all invested efforts, the water quality and quantity continue to be impacted by excessive exposure to various sources of pollution (BAMAS, 2005a and b).

All this calls for the immediate intervention through the development and implementation of integrated river basin management (IRBM). Instating and sustaining IWRM will ensure the coordination, conservation, management and development of water, land and related resources across all sectors of the river basin. This is essential to "maximize the economic and social benefits derived from water resources in an equitable manner while preserving and, where necessary, restoring freshwater ecosystems" (Global Water Partnership, 2000).

3. STUDY OBJECTIVES AND WORK PLAN

In lieu with the above presented goals, the objective of this study is to update the water quality inventories that were conducted in 2005 under the USAID-funded activity of the Litani Basin management Advisory Services (BAMAS). As such, the direct objectives are to (a) evaluate the Upper Litani Basin water quality profile, (b) compare to results of previous studies (BAMAS 20005), (c) reflect on possible risks associated with multipurpose water usage, and accordingly (e) propose mitigation measures. Accordingly, the specified tasks related to:

1. Conducting an extensive literature review (BAMAS winter and summer technical surveys),
2. Developing a framework for the sampling campaign (Litani River and its tributaries, Qaraoun Lake; Irrigation Canal 900, main domestic and industrial wastewater discharged effluents, groundwater springs and wells, soil and river and lake sediments),
3. Conducting a rapid field survey to update the inventory of potential sources of pollution,
4. Proposing a list of sampling locations (with GPS coordinates),
5. Developing procedural guidelines and log forms for the collection of samples,
6. Sampling and analytical quality determination,
7. Evaluating water acceptability for multipurpose usages, based on set national and international standards,
8. Analyzing the water quality profile and comparing it to the results of the BAMAS 2005 study in terms of geographic hot points and trends, and presenting data using suitable tables, maps and graphs,
9. Documenting point sources of pollution (e.g. Industrial effluents, sewage effluents, landfill effluents, wastewater treatment effluents), and
10. Recommending interventions for improved practices and mitigation/control measures for the main sources of pollution and main types of pollutants.

4. STUDY METHODOLOGY

4.1. PREPARATORY WORK

Prior to developing the framework for the sampling campaign, and in preparation for the field survey, the following was insured:

1. Revision of the current situation of the Upper Litani Basin (major projects, initiatives, recent publications and reports),
2. Revision of the Litani Basin Advisory Services (BAMAS) 2005 technical reports (rapid review, winter and summer technical surveys), and
3. Consultation and coordination with the Litani River Basin Management Support Program (LRBMS).

4.2. SAMPLING CAMPAIGN FRAMEWORK

Based on available maps, and in line with the BAMAS 2005 Report, and in consultation with the (LRBMS) group, the sampling campaign was developed to cover:

a. The Litani River and its Tributaries,
b. The Qaraoun Lake,
c. Irrigation Canal 900
d. Groundwater springs and wells located within the ULB,
e. Domestic wastewater(sewage) effluents (from residential communities) disposed directly through sewer outlets,
f. Major industrial wastewater effluents (resulting from major industries) disposed directly into the river,
g. Soils of agricultural areas bordering the river, and
h. River and Lake sediments

4.3. FIELD AND RECONNAISSANCE SURVEYS

Over a period of 16 days (July 9, July 12- 17, July 19 -24 and July 26-30, 2010) a complete inventory of major cities and villages located within the Upper Litani Basin (URB) was conducted. The area was screened to collect the required information to update all potential point and non-point sources of pollution. Logistically, and to facilitate the work, the Upper Litani Basin was divided into 3 sub-entities:

1. Yellow Zone (Upper Zone) between Saidi and Rayak (Saidi, Housh Barada, Taraya, Housh Sneid, Chemistar, Hezeine, Bednayel, Housh Rafka, Sifri, Temnine Al Fawka, Temnine Al Tahta, Ablah, Ferzol, Rayak, Yahfoufa, Janta, Masa, Seraine and Helaniyeh),

2. Orange Zone (Middle Zone) between Rayak and Ammiq (Qaa El Reem, Hazerta, Zahle, Amrousieh, Jdeita, Chtoura, Tannayel, Jalala, Anjar, Majdel Anjar, Saadnayel, Bar Elias, Dier Zanoun, Housh Al Harimi, Faour, Dalhamyieh and Al Marj), and

3. Green Zone (Lower Zone) between Ammiq and Qaraoun (Kobb Elias, Tal Al Akhdar, Ammiq, Housh Ammiq, Al Marj, Mansoura, Ghazza, Luci/Sultan Yaakoub, Kherbeit Kanafar, Ain Zebdeh, Jeb Janine, Kamed Al Louze, Saghbeine, Lala, Dier Ain Al Jawzeh, Bab Merea, Baaloul, Aitaneit and Qaroun)

A total of 58 major cities and villages on both sides of the Upper Litani Basin were screened. To ensure the uniform and comprehensive data collection, field forms were developed (see appendices).

Concurrent with the field survey, a comprehensive reconnaissance study to screen water quality and determine sampling sites was conducted. The results of the reconnaissance study are presented in appendices. Additionally, maps reflecting on urbanization pressures, type of land cover, and the location of sampling points along the Upper Litani Basin are presented in Figures 1-4.

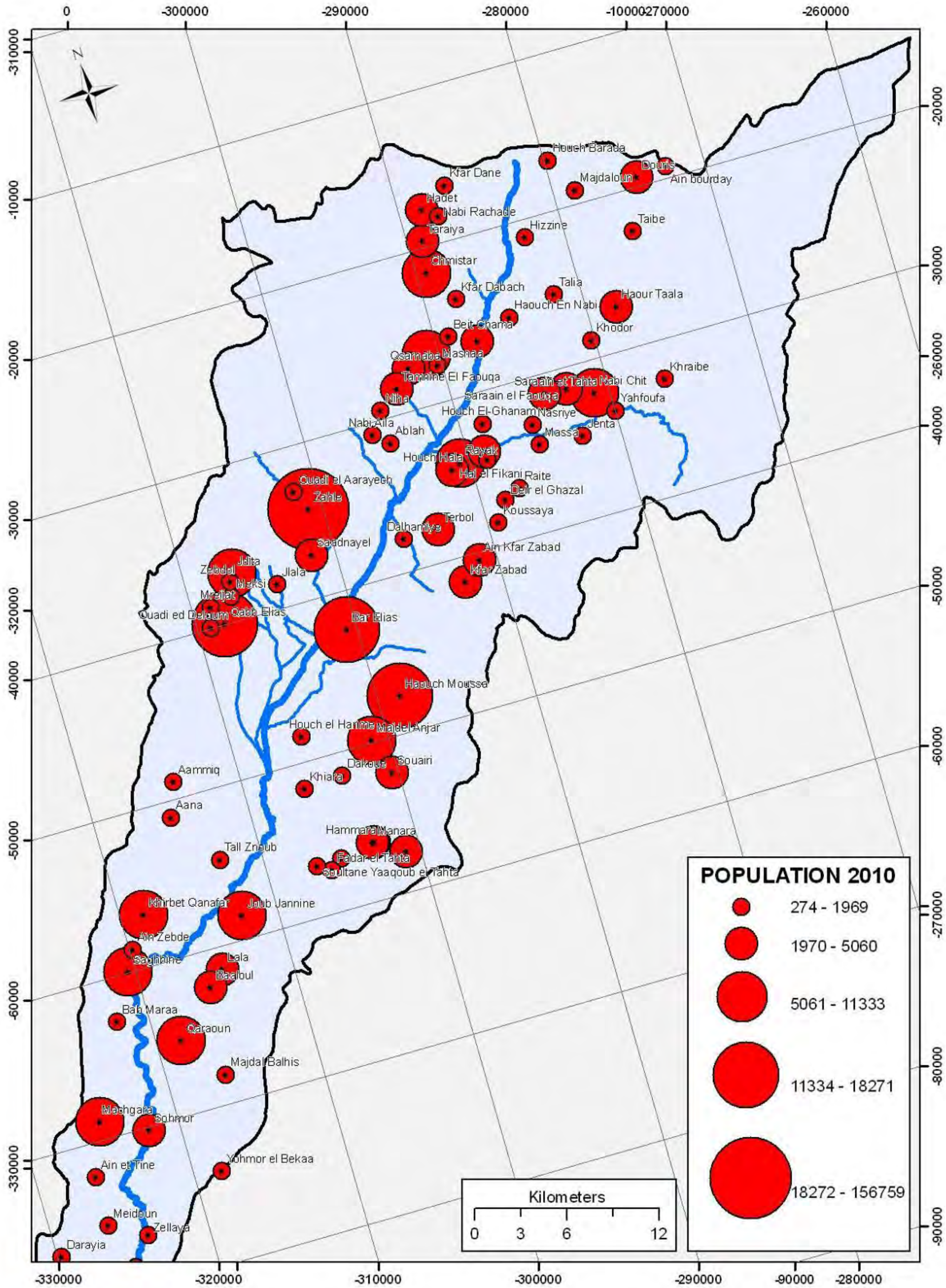


Figure 1: Upper Litani Basin Urbanization Profile

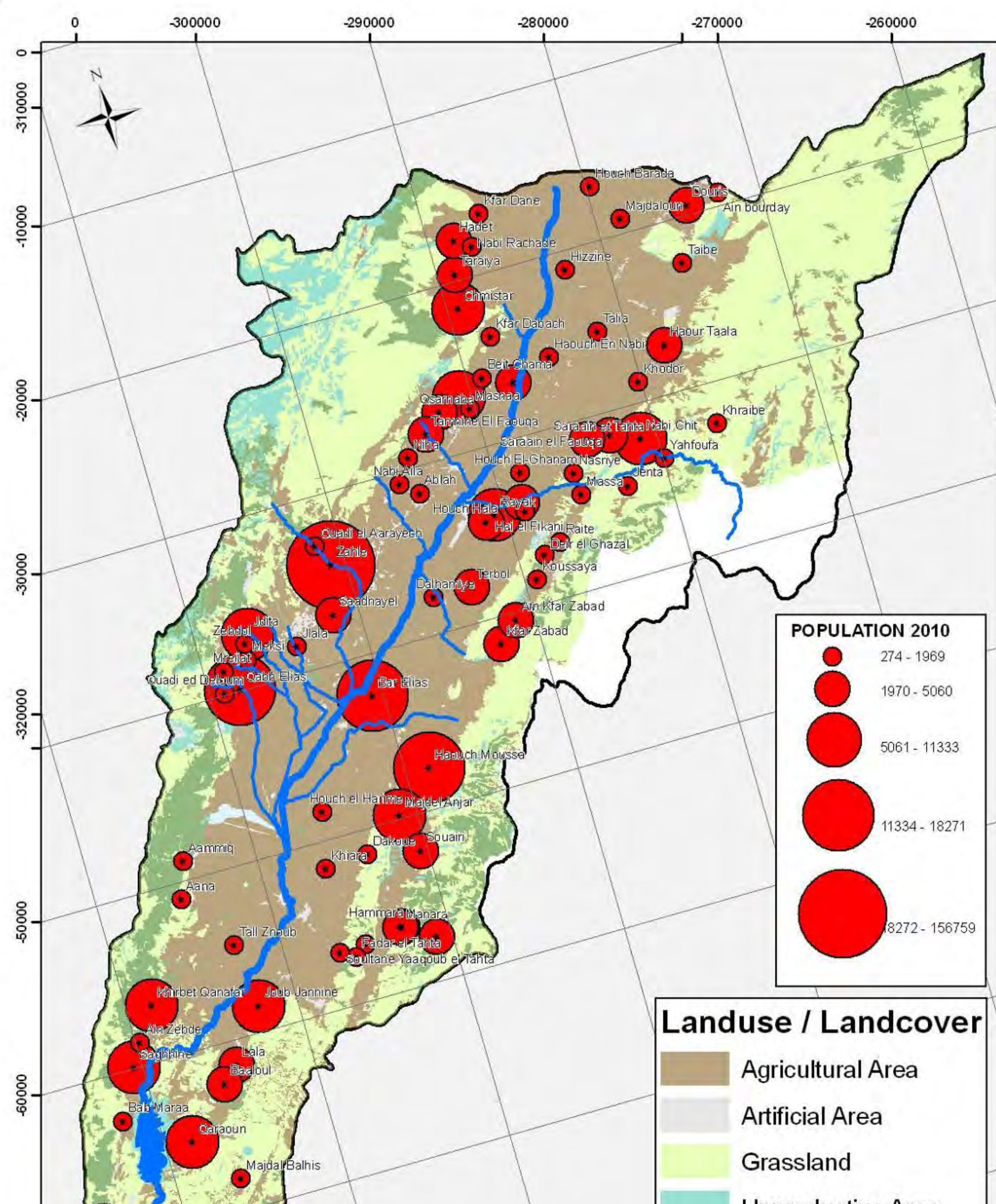


Figure 2: Upper Litani Basin Landuse and Landcover Profile

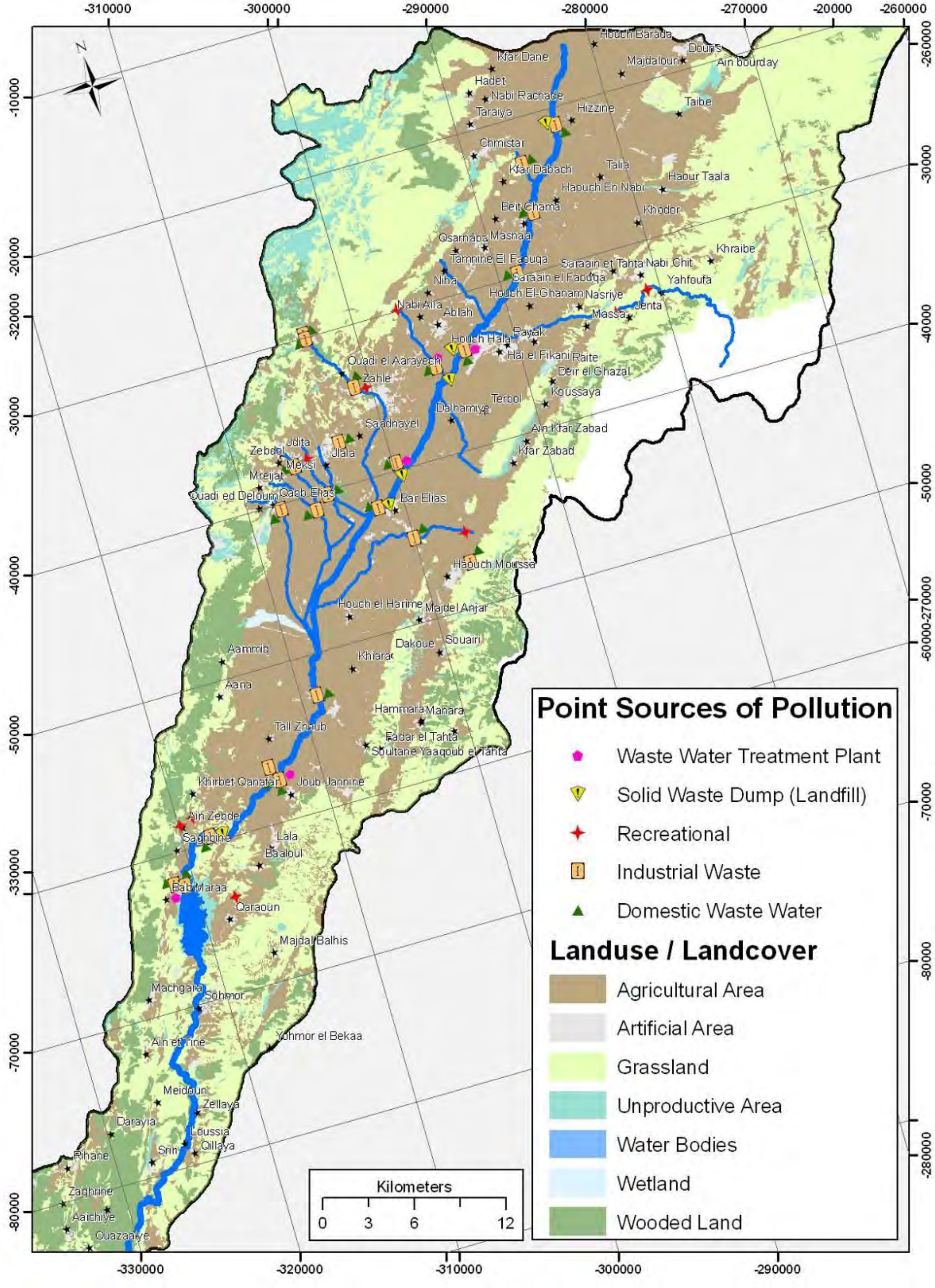


Figure 3: Upper Litani Basin Point and Non-Point Sources of pollution

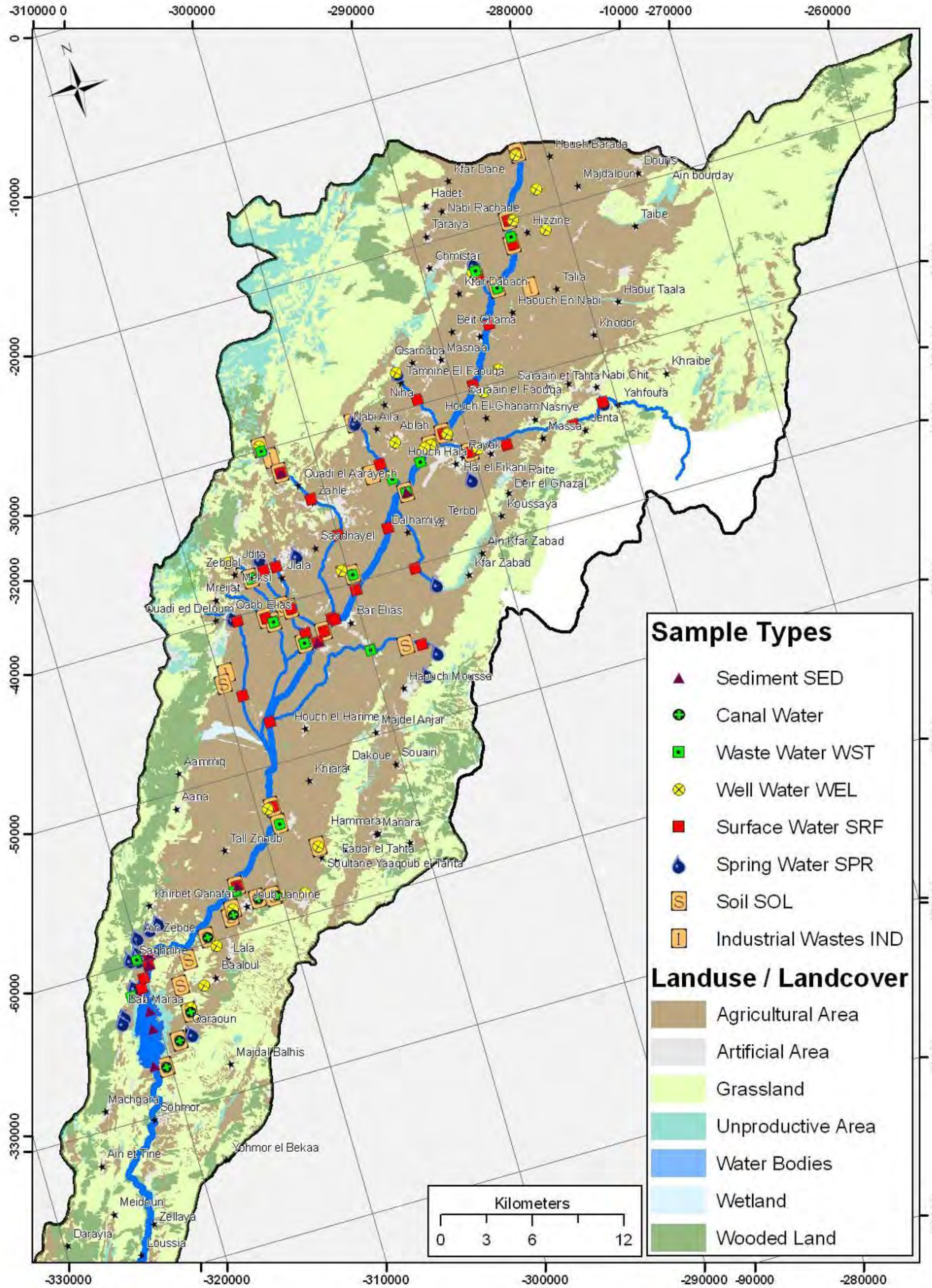


Figure 4: Upper Litani Basin Types and Location of Samples

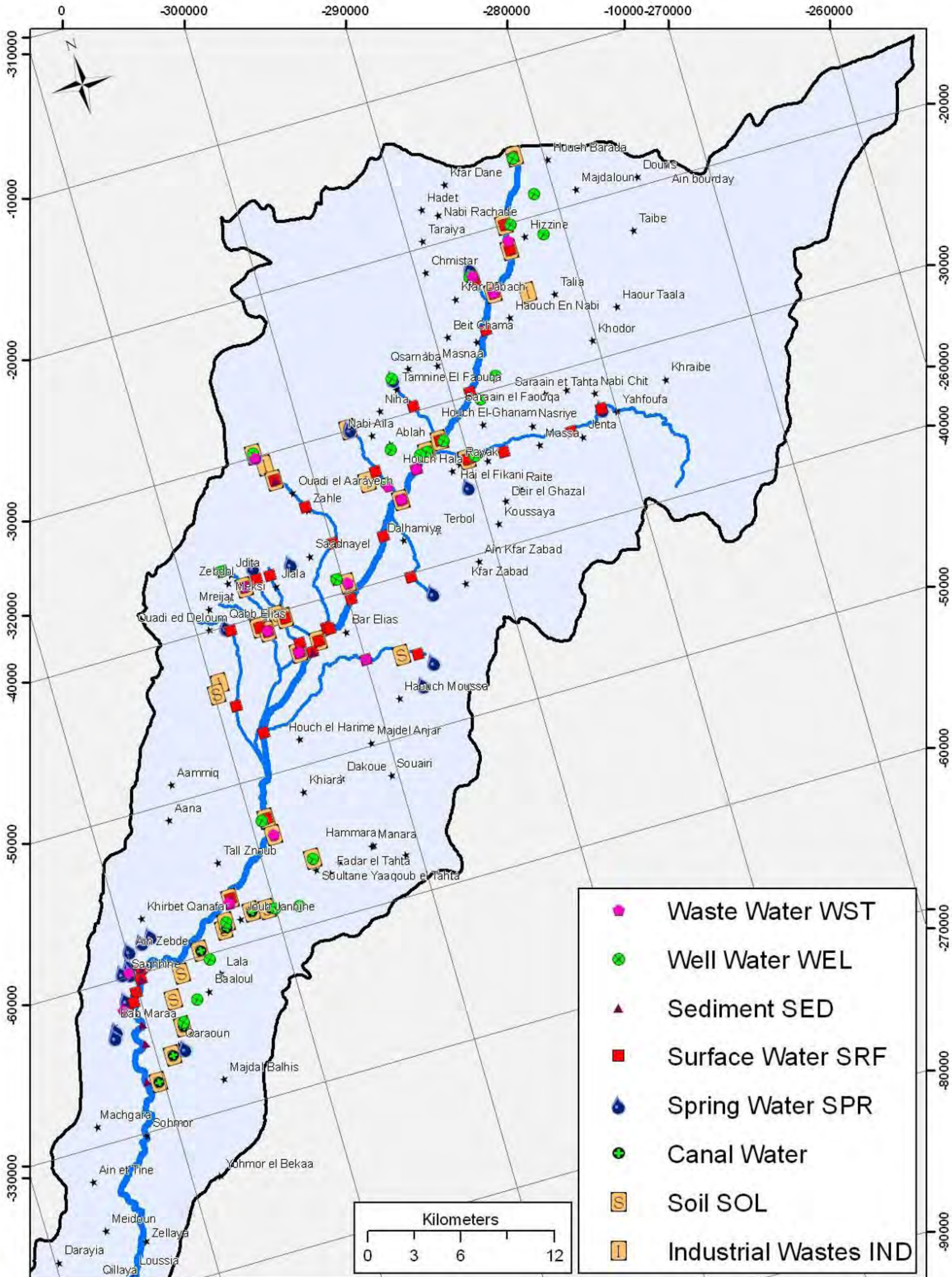


Figure 4a: Upper Litrani Basin Types and Location of Samples

4.4. DETERMINING ULB SAMPLING LOCATIONS

4.4.1. SAMPLING THE UPPER LITANI BASIN

Based on the findings of the field and reconnaissance surveys, the sampling points along the river (all river samples were collected directly at subsurface points as the water depth was minimal that did not exceed 25-50 cm), river sediments, ground water (springs and wells), domestic wastewater (sewage), industrial wastewater, soil and sediments were located as presented in figures 5-11.

In addition, the determined sampling points were compared to the sampling points identified by the BAMAS 2005 Study. The comparison clearly reflects on the comprehensive coverage of the ULB study area in the present study.

Additionally, the number of collected samples from the different sampling sites is also presented in appendices along with the corresponding GPS reference numbers and coordinates.

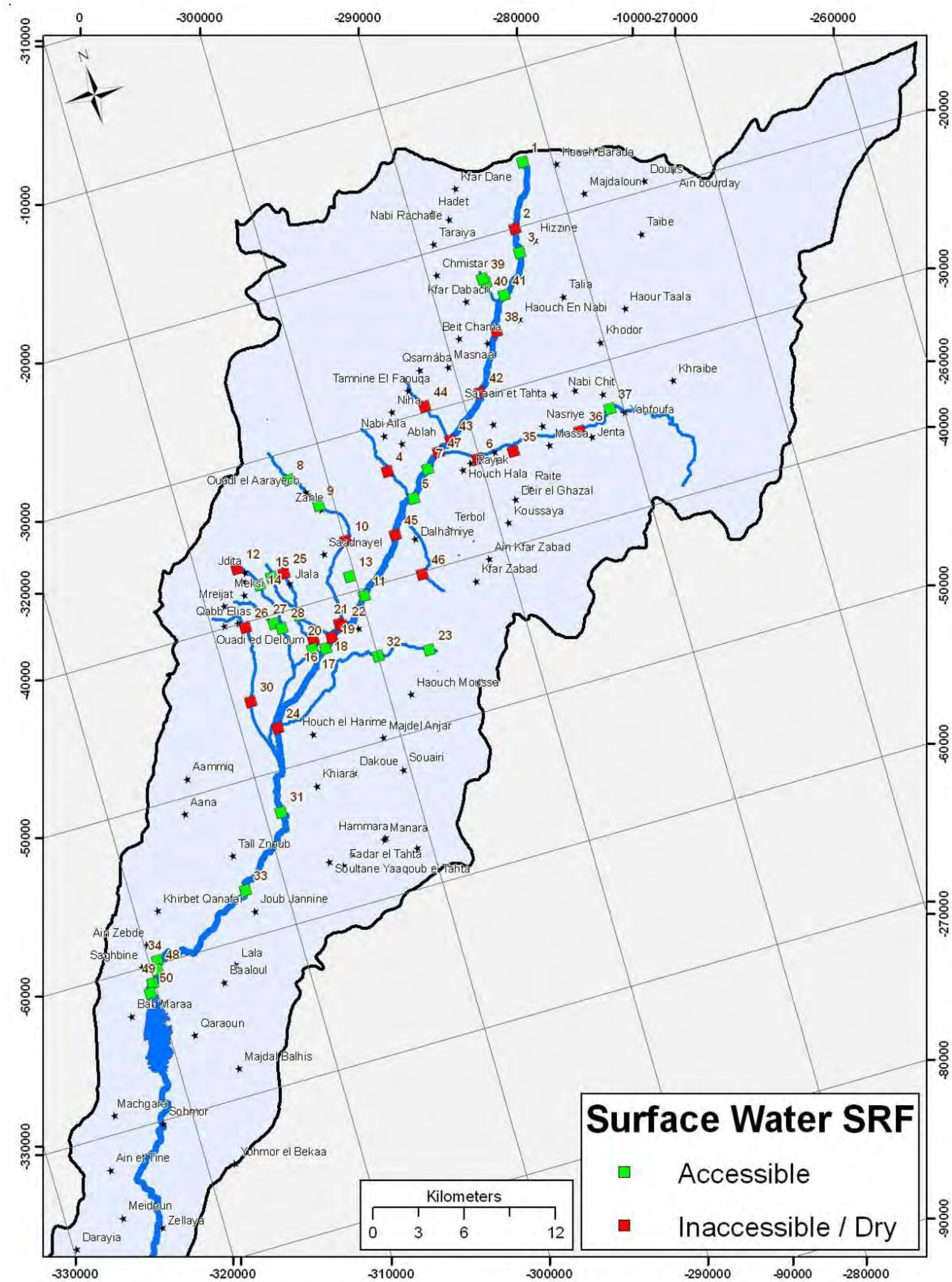


Figure 5: Location of Surface Water Sampling Points along Litani River and its Tributries

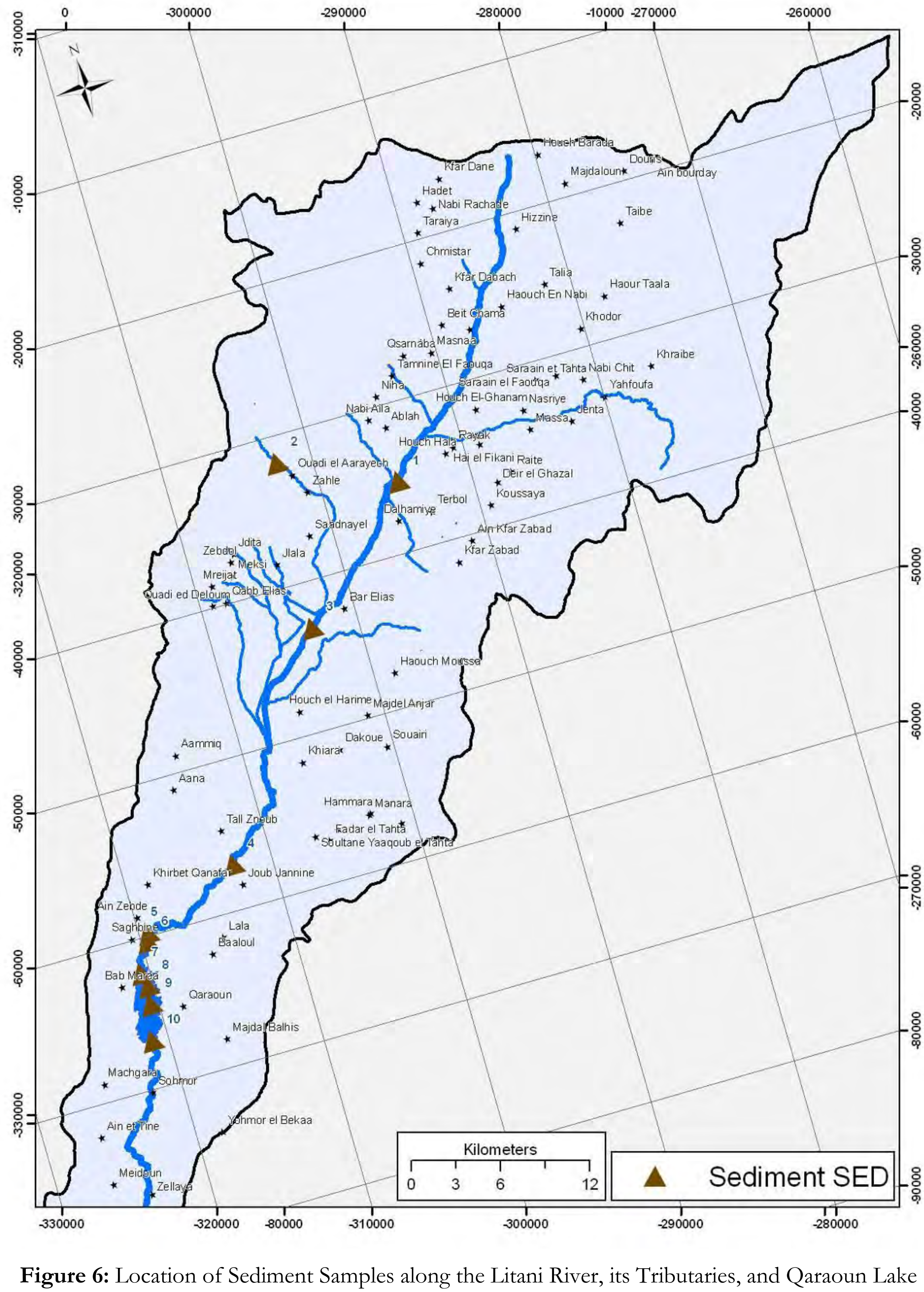


Figure 6: Location of Sediment Samples along the Litani River, its Tributaries, and Qaraoun Lake

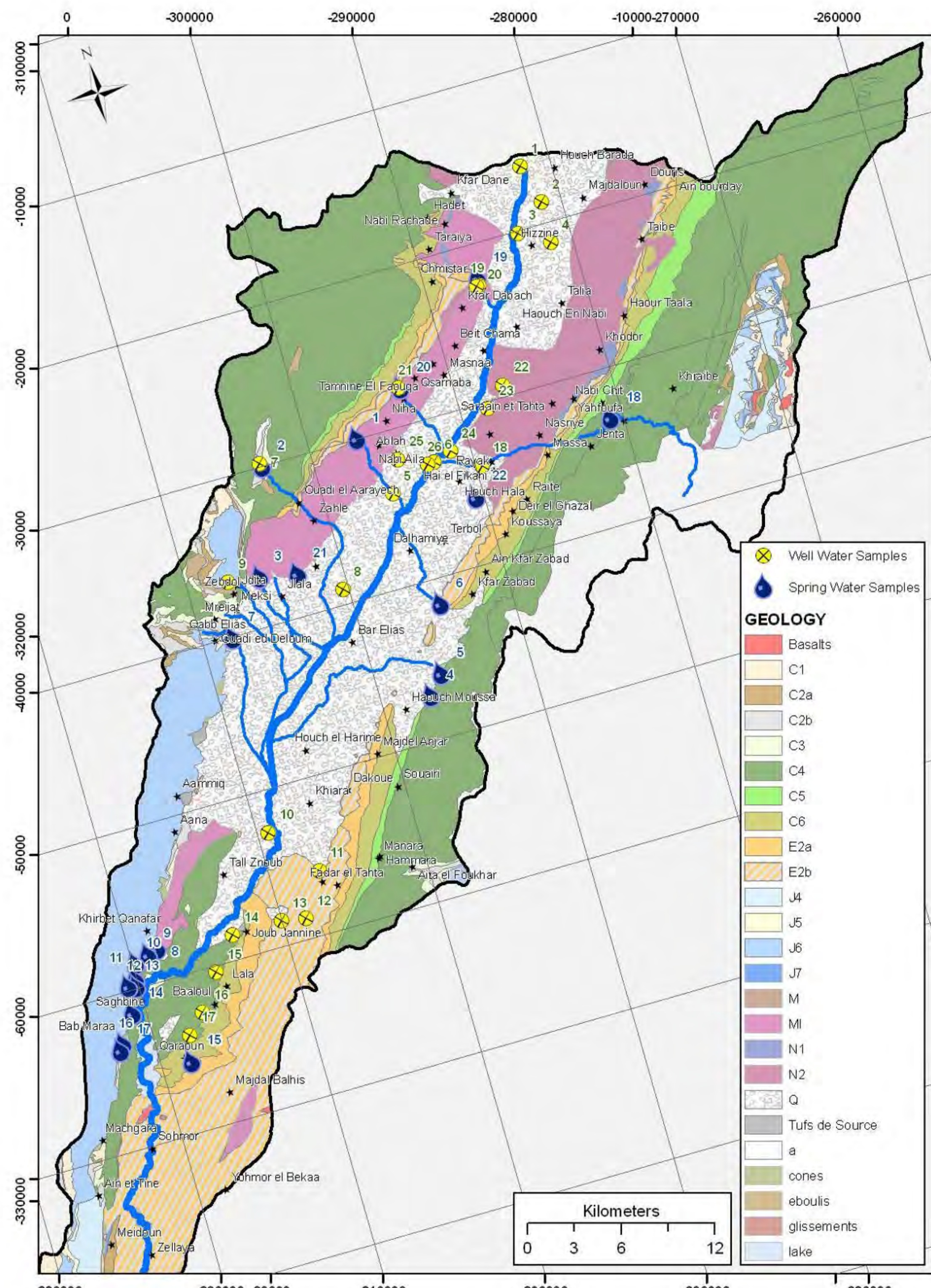


Figure 7: Location of Groundwater Samples along the Litani River and its Tributaries

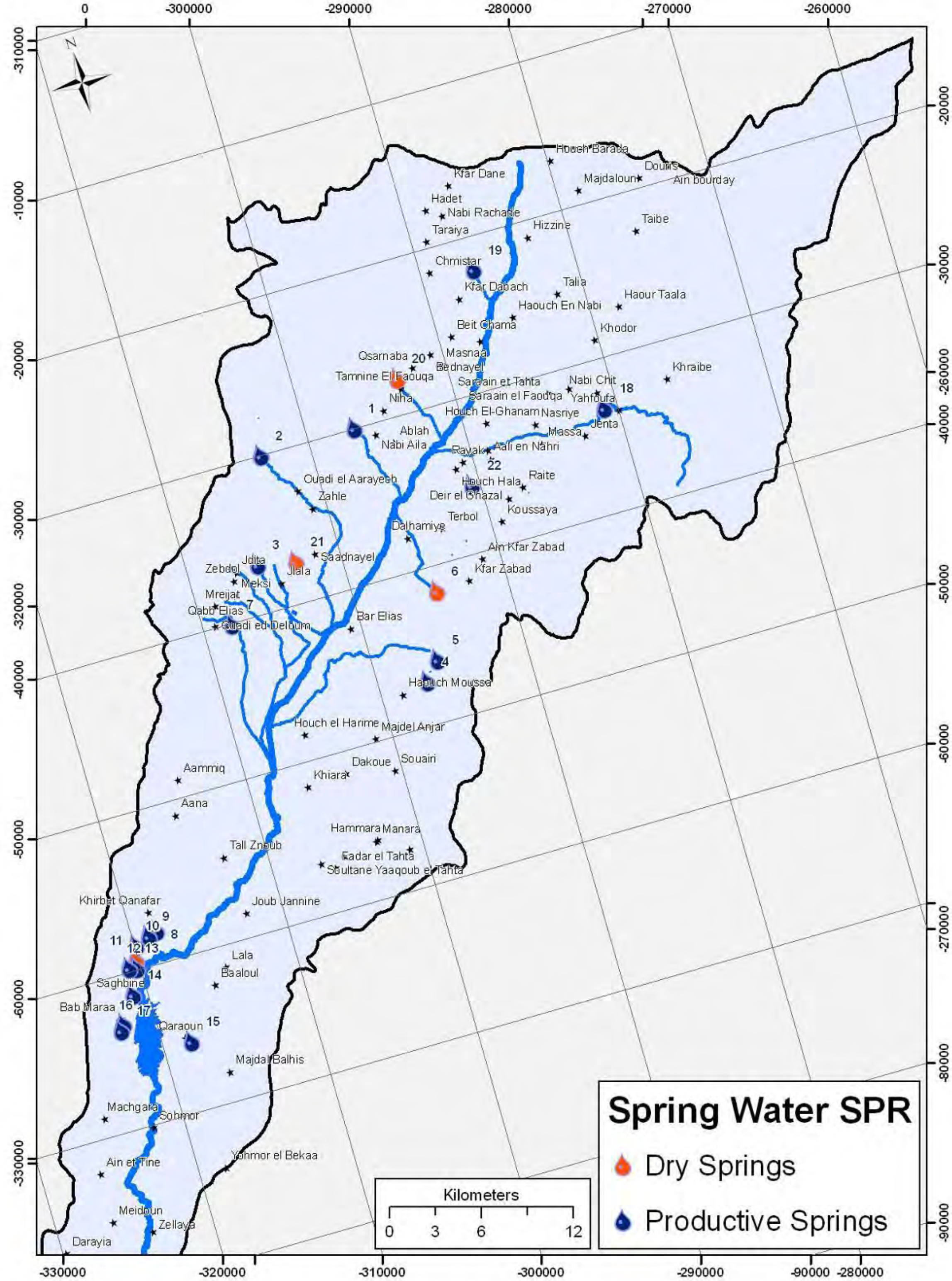


Figure 8: Location of Springs Water Samples along the Litani River & its Tributaries

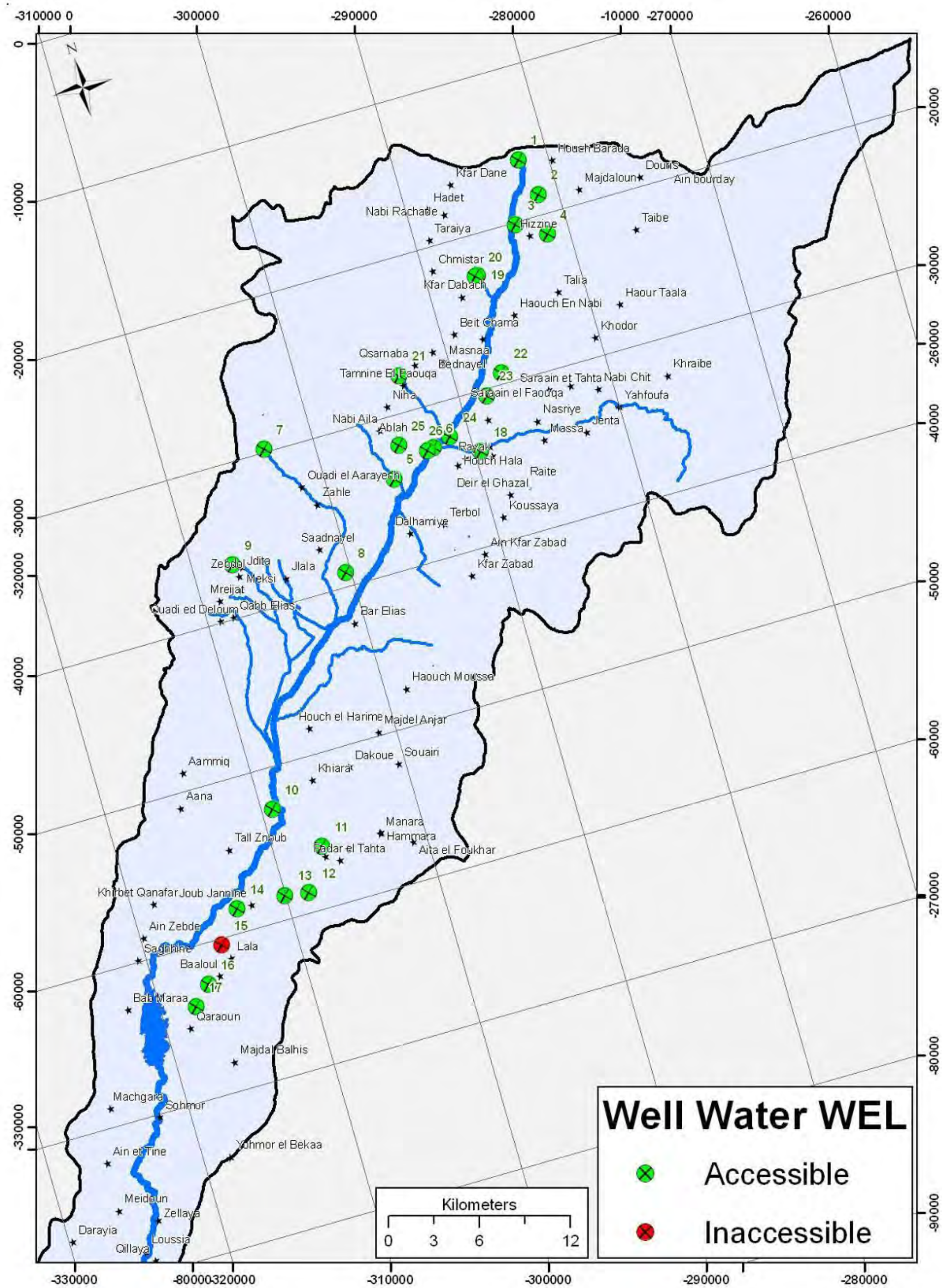


Figure 9: Location of Well Samples along the Litani River & its Tributaries

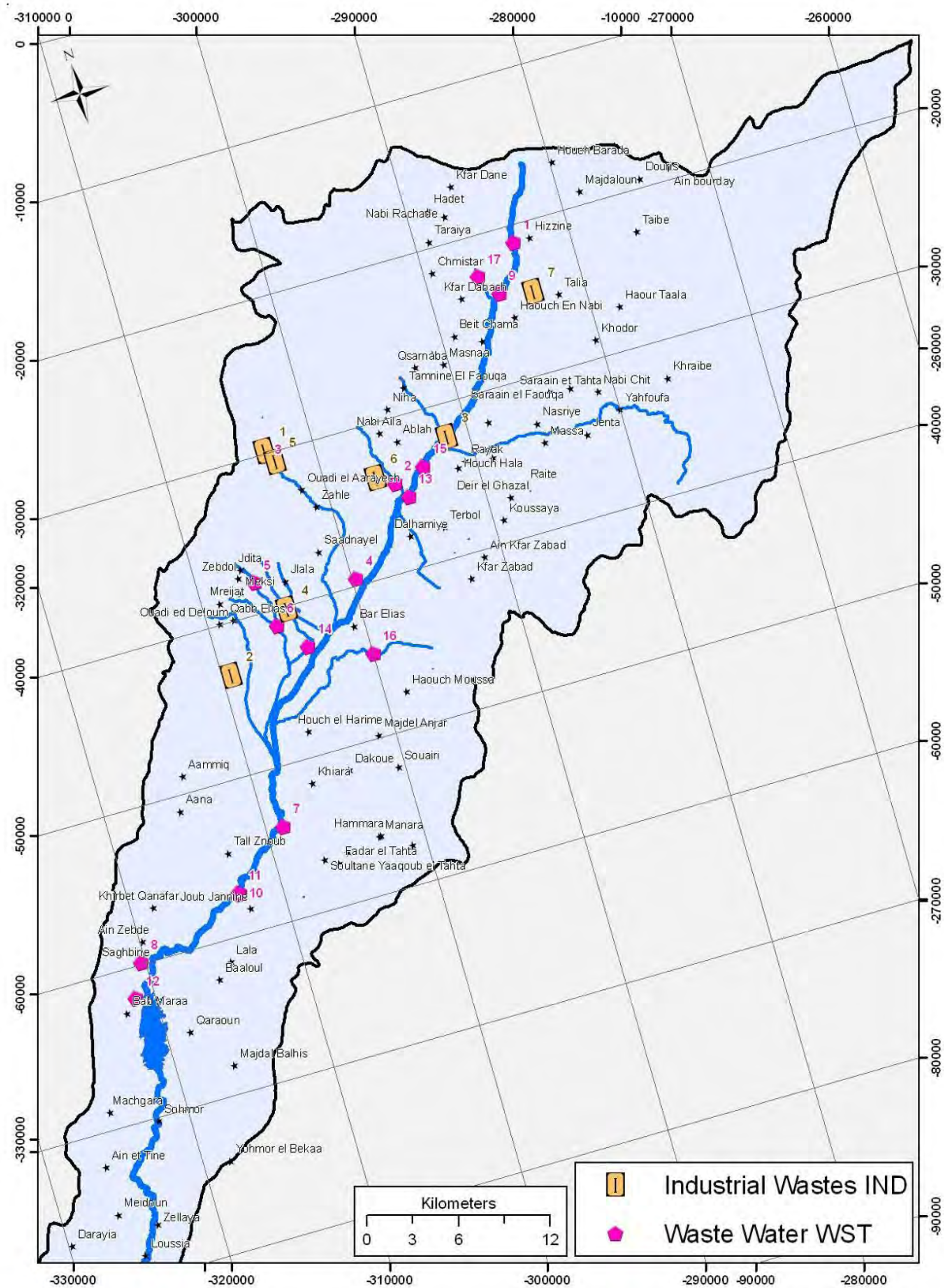


Figure 10: Location of waste water & Industrial Waste Samples along the Litani River & its Tributaries

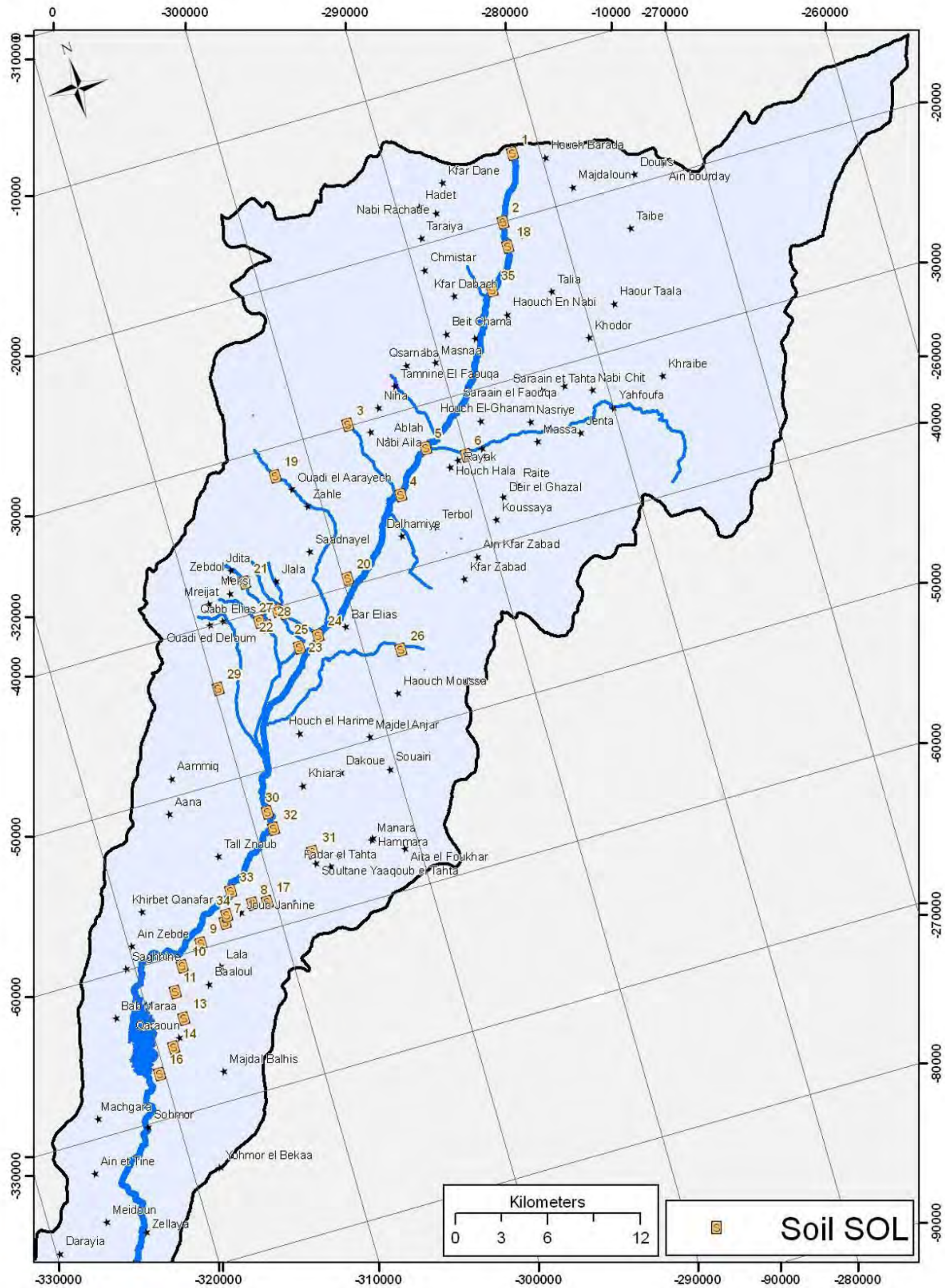


Figure 11: Location of Soil Water Samples along the Litani River & its Tributaries

4.4.2. SAMPLING THE QARAOUN LAKE

The Qaraoun Lake can store up to 220 MCM of water (Figure 12). Geologically, the rocks outcropping in the Qaraoun Lake basin belong to the Jurassic, Cretaceous, Tertiary and Quaternary systems. Most of the rocks of the Jurassic system (J6), Cenomanian (C4) and Eocene (e2b) are limestone and dolomitic limestones. In a few localities, Conomanian rocks (C3 and C6) outcrop consisting mainly of chalky marl is present. As for the Quaternary deposits (q), they are limited and comprise mainly alluvial deposits consisting of clay, silt, sand and gravel (Khair, 1993; Owaydah, 1993; Jurdi et al., 2002). The quality of lake water and sediments have been extensively studied by the project consultants, and three major water quality zones have been identified (Jurdi and Korfali, 2002; Korfali and Jurdi, 2006). Accordingly, the eleven sampling sites were located to reflect on the three previously defined water zones:

1. Receiving Zone (S3-S5)
2. Central Zone (S5-S10)
3. Dam Zone (S10-S13)

In addition, a total of 4 lake sediment samples were collected to reflect on conditions within the three identified lake water zones, as presented in figure 13.

Figure 12: Overview of the Qaraoun Lake

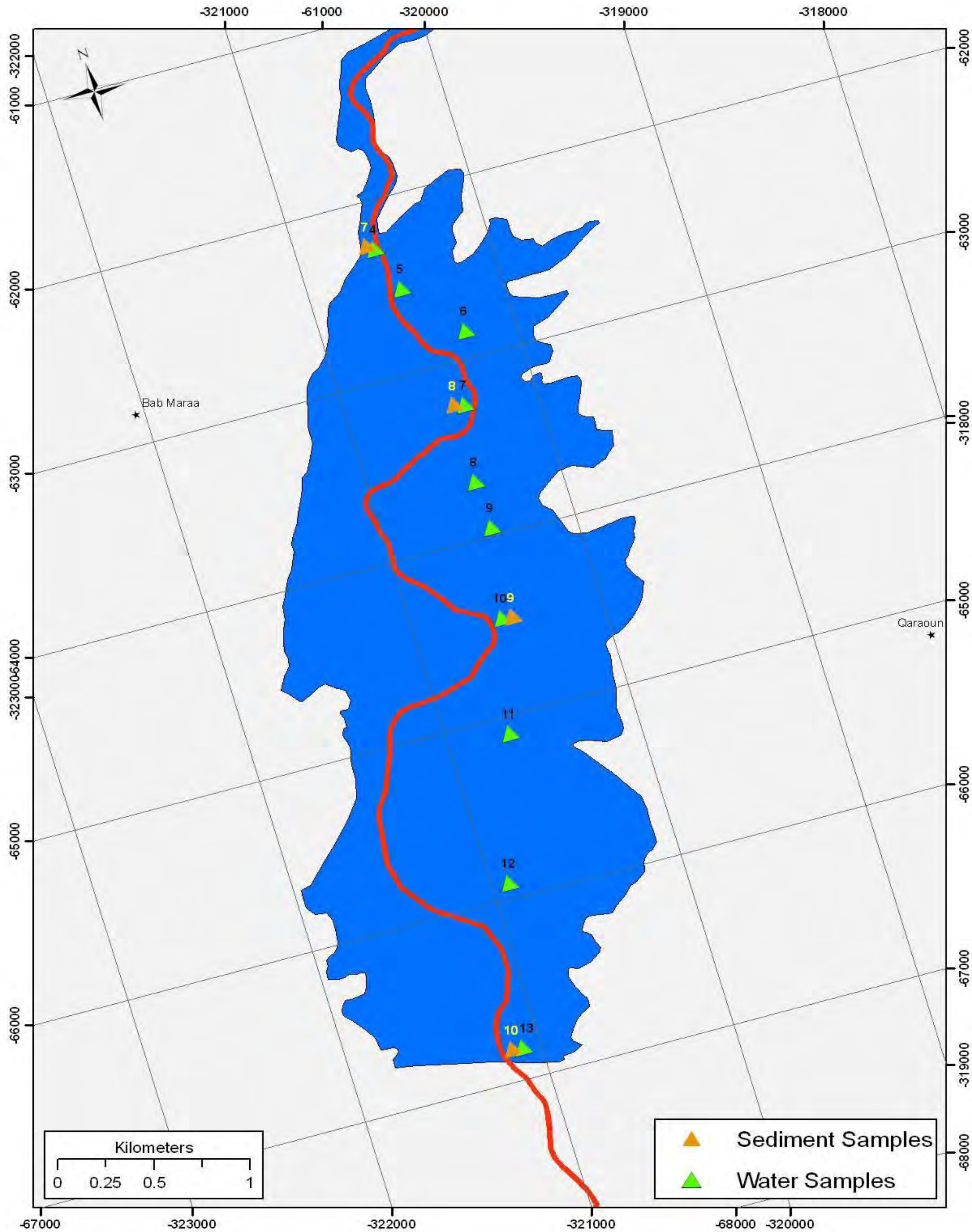


Figure 13: Location of Water and Sediments Samples along the Qaraoun Lake

4.4.3. SAMPLING IRRIGATION CANAL 900

Irrigation canal 900 is an open lined channel 18.5 km in length. It is divided roughly into four equal segments of an average slope of 0.2 % (Figure 14). The canal is designed to deliver 30 MCM per year (m^3/yr) and irrigates approximately 2,000 hectares. The irrigation water is pumped from the Qaroun Lake, flows through the Canal across Baaloul, Lala, Jeb Janine and Kamed Al Louze (BAMAS 2005c).

Water flow is regulated by 3 pumping stations/towers in Qaroun (T1), Jeb Janine (T2) and Kamed Al Louze (T3) that subsequently service laterals that irrigate adjacent agricultural lands. Major irrigated crops include wheat, potatoes, onions, seasonal vegetables, water melons and apples. Water is mostly pumped between May and September, an approximate 7 month/year (BAMAS 2005c).

Based on the reconnaissance survey 6 water sampling points were selected to reflect on the quality of the irrigation canal, as presented in Figure 15. Additionally, soil was sampled from agricultural lands, east and west of water sampling points.

Figure 14: Irrigation Canal 900

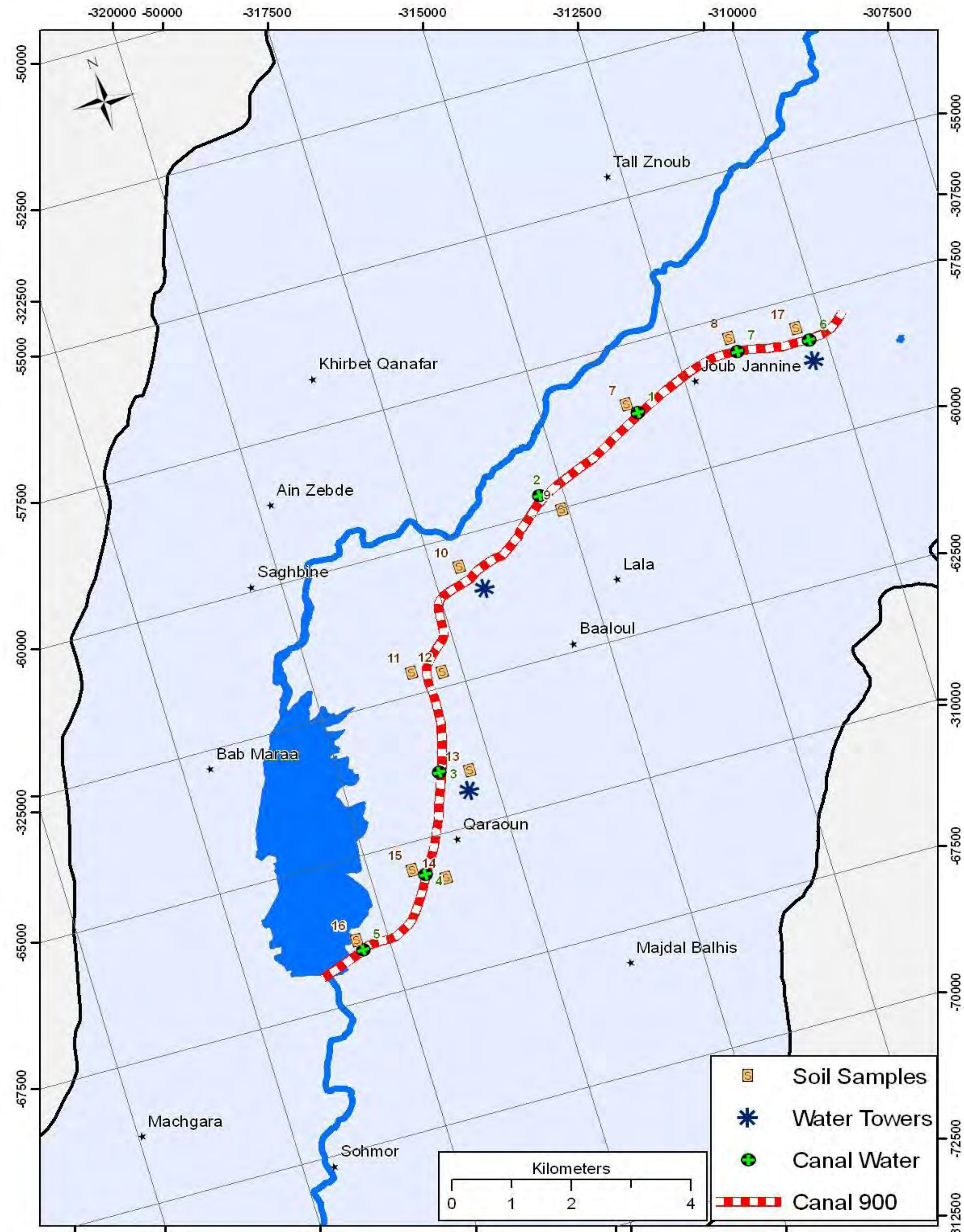


Figure 15: Location of Water & Soil Samples along the Canal 900

4.5. DEVELOPMENT OF PROCEDURAL GUIDELINES AND LOG FORMS FOR SAMPLE COLLECTION

Prior to sample collection, procedures and guidelines were developed based on standard methods for sample collection (Standard Methods for the Examination of Water and Wastewater, 21st Edition, 2005). Additionally, sample log forms were also developed for the accurate recording of sample characteristics. The developed sample log forms are presented in appendices.

4.6. SAMPLING AND ANALYTICAL QUALITY DETERMINATION

The collected samples were analyzed at the Water Quality Assessment and Management Research Unit (Associate Research Unit funded by the Lebanese National Council for Scientific Research and in collaboration with the Lebanese American University). Analytical work in this research unit is governed by standard procedures and Methods (Standard Methods for the Examination of Water and Wastewater, 21st Edition, 2005).

Analytical testing of temperature, dissolved oxygen, pH, electrical conductivity (EC), total dissolved solids (TDS) and salinity were conducted Onsite. Water samples for physical and chemical analysis were collected in polyethylene bottles that were presoaked overnight in 10% (v/v) nitric acid and then rinsed with distilled water. Sampling was done in accordance with standard methods recommended by the American Public Health Association, the American Water Works Association, and the Water Pollution Control Federation (Standard Methods for the Examination of Water and Wastewater, 21st Edition, 2005). On the other hand, water samples for microbiological testing, were collected in sterile borosilicate 300 ml bottles. All samples were transported in ice boxes to the laboratory.

Upon delivery to the laboratory, water samples were filtered (when needed) and divided into two parts: one for physical and chemical macro-elements testing and the other (acidified with nitric acid to pH <2 and stored at 4^0C) for trace metals testing. Water samples for pesticide residues testing were collected in amber bottles, transported to the laboratory in cold storage and stored at 4^0C till extraction. Extracted sample were restored at 4^0C, for a maximum of 40 days prior to analytical testing.

The various physical, chemical and microbiological parameters were determined by standard methods and procedures (APHA, AWWA, WPCF, 2005) as presented in table 1. Furthermore certified prepared reagents (EPA Standards) of HACH Chemical Company (USA) were used, and recommended quality control measures were implemented.

Table 1: Standard Analytical Method for the Determination of the Physical, Chemical and Microbiological Quality Parameters

Type of Sample	Analytical Parameter	Standard Analytical Method	Type of Analytical Equipment
Water	**pH**	Electrometric method	SensIon 7 HACH, pH Meter
	Electric conductivity	Electrical Conductivity Method	SensIon 7 HACH, Conductivity Meter
	Alkalinity	Titration Method using Sulfuric Acid Standard Solution (0.02N)	Burret Titration
	Nitrates	Cadmium Reduction Method	DR 2800 HACH Spectrophotometer
	Phosphates	PhosVer 3 (Ascorbic Acid) Method	DR 2800 HACH Spectrophotometer
	Sulfates	SulfaVer 4 Turbidimetric Metod	DR 2800 HACH Spectrophotometer
	Ammonia	Nessler Method	DR 2800 HACH Spectrophotometer
	Sodium & Potassium	Flame Photometry	JENWAY Flame Photometer
	Calcium & Magnesium	EDTA Titration Methods	Buret Titration
	Chlorides	Mercuric Nitrate Titration Method	Buret Titration
	DO & BOD5	Electrode Methods	SensIon 6 HACH, DO Meter
	Organochlorines & Orgnophosphates	Liquid- Liquid Extraction, GC/MS	Liquid- Liquid Extraction GC/MS
	T. Coliform, E. *coli* & Strep. *feacalis*	Membrane Filter Technique	Millipore Filtration
Soil	PH, Electric Conductivity (EC)	Extraction and electrode Method	XRF-NITON XL3t Thermo Scientific

	Nitrates	X Ray Fluorescence	XRF-NITON XL3t Thermo Scientific
	Phosphates	X Ray Fluorescence	XRF-NITON XL3t Thermo Scientific
	Sulfates	X Ray Fluorescence	XRF-NITON XL3t Thermo Scientific
	Ammonia	X Ray Fluorescence	XRF-NITON XL3t Thermo Scientific
	Chlorides	X Ray Fluorescence	XRF-NITON XL3t Thermo Scientific
	Soluble Sodium & Potassium	X Ray Fluorescence	XRF-NITON XL3t Thermo Scientific
	Soluble Calcium & Magnesium	X Ray Fluorescence	XRF-NITON XL3t Thermo Scientific
	Trace Metals: Mg Pb. Cd, Cr, Zn, Fe, Al, As, Ba, Co, Bo, Mn &Mo	X Ray Fluorescence	XRF-NITON XL3t Thermo Scientific

5. RESULTS AND DISCUSSION

5.1. RESULTS OF THE FIELD STUDY OF THE ULB

Screening the cities and villages of the Upper Litani Basin and reflecting on (a) the quality and type of environmental services provided for the management of municipal solid waste and domestic wastewater(sewage), (b) the lack of compliance in implementing onsite measures to insure the proper management of the various sources and types of industrial wastes (solid and liquid), (c) the excessive dependence on groundwater and raw untreated sewage as a source of irrigation water, (d) the excessive application of pesticides, fertilizers and animal manure, (e) the flourishing "query business" and the prevalence of stone cutting open sites, and the direct location of recreational activities along the river bank and its tributaries; clearly defines the major point and nonpoint sources of pollution. In summary these sources of pollution relate to:

1. Domestic Wastewater (sewage); cesspools discharges and sanitary sewer system outlets,
2. Municipal solid waste dump sites,
3. Agricultural runoff,
4. Food processing plants (e.g. sugar beet, dairy products, fruit jam, and juices, vegetable canning) wastewater effluents,
5. Industrial zones (dyeing and tanning, electroplating, manufacturing of batteries, chemicals, sponge and paper) wastewater effluents,
6. Farm (swine, cows, sheep and poultry) waste, and
7. Recreational areas (hotels and restaurants) sewage discharge and solid wastes dump sites.

5.1.1. THE YELLOW ZONE (UPPER ZONE OF THE ULB)

This zone of the Upper Litani Basin (between Saidi and Rayyak) is mainly characterized by mixed residential, agricultural and industrial activities. The river flow is relatively minimal, mostly non-existing and is mainly sustained by domestic (sewage) and industrial wastewater effluents. Hence, the water is mostly stagnating, has a foul smell, a dark black color and supports the excessive growth of Bamboo and Lavender plants (figures 16-19).

Moreover, this zone contributes 4 major water tributaries that feed into the Upper Litani Basin; two of which are dry in summer:

1. The Housh Bay Tributary,
2. The Temnine Tributary (dry in summer),
3. The Habbis/Ferzsol Tributary (dry in summer), and
4. The Yahfoufa/ Hala Tributary.

The Management of municipal solid waste is highly deficient and solid waste dump sites are scattered throughout the area. As for the management of domestic wastewater, sanitary sewer systems and cesspools are the main venues for disposal. At present, the only existing wastewater treatment plant (secondary/biological treatment) is located in El Ferzol. Yet, the disinfection of the final treated effluent prior to disposal is still deficient. Another treatment plant in Ablah is still under construction (early phase of project).

Agricultural activities in this zone mostly relate to tobacco plantation, wheat and seasonal vegetables. Dependence on sewage and ground water, as sources of irrigation water, is excessive as "mostly" the river flow is minimal, if not dry. And farmers complain from the drying of shallow wells due to the excessive ground water extraction by "large scale farming projects". Additionally, sewage is almost "completely" tapped for irrigation and the sanitary sewer outlets along the river, in summer, are dry with stagnating pools of sewage (figures 16-19).

Moreover, the industrial activities in this zone are various ranging from small to large scale dairy plants (e.g. Leban lait), food processing plants (e.g. Master Chips & Tanmeyah) to rock cutting industries, plastic and paper industries. The industrial wastewater effluents are discharged directly into the river and its tributaries, or are disposed into the city/village sewer that outflows into the surface water body. This is increasing the organic load of contaminants and subsequently the biochemical oxygen demand (BOD) and will be discussed in details furthermore on in this report.

The detailed description of the profiles of cities and villages within the yellow zone of the ULB is presented in appendices. Additionally, the identified point and non point sources of pollution and the selected sampling sites (river water, springs, wells, domestic and industrial wastewater effluents, soil and sediments) are presented in appendices.

Figure 16: Sewage Discharge in Temine El Tahta

Figure 17: Tanmiyeh Discharge in Ablah

Figure 18: Litani River in Housh Barada

Figure 19: Litani River in Hezeine

5.1.2. THE ORANGE ZONE (MIDDLE ZONE OF ULB)

This middle region of the Upper Litani Basin is mainly characterized by mixed residential, agricultural, industrial (active sector) and recreational (active sector) activities. The river flow is minimal and heavily exposed to sewage and industrial wastewater discharge. Moreover, the water is blue green in color due to the extensive growth of algae, and the presence of tadpoles, water snakes, fish and turtles is evident (Figures 20-23).

This zone of ULB contributes to the river flow five major tributaries that are either dry (in summer) or completely tapped for irrigation:

1. The Berdawni Tributary (tributary dry before the joining point with the Chtoura Tributary in the Marj Area, as the water is "completely" tapped for irrigation),
2. The Chtoura Tributary (the Jdeita spring, one of the two spring outflows that form this tributary, is dry in summer),
3. The Ghzayel Tributary (mainly stagnating sewage in summer),
4. The Faour Tributary (dry in summer), and
5. The Jalala Storm Water Runoff (dry)

The major landfill used for the final disposal of municipal solid waste is located in Zahle. Yet, municipal solid waste dump sites are found in cities and villages that do not transfer their municipal solid wastes to the Zahle "sanitary" landfill. As for the management of domestic wastewater (sewage), sanitary sewer systems (mostly) and cesspools (minimally) are the main venues of disposal. Additionally, a sewage treatment (secondary/biological) plant located between Housh Al Oumara and Bar Elias is under construction.

Agricultural activities in this zone mostly relate to growing of seasonal vegetables. Dependence on sewage and river tributaries is excessive. Most sewage outlets are completely dry as sewage is "mostly" tapped for irrigation. In addition, tributaries originating from water springs are also "completely" tapped for irrigation, reflecting on minimal water flow in the main river bed where these tributaries should be flowing.

Moreover, this zone is characterised by an active industrial sector. Industrial activities range from small to large scale dairy plants (e.g. Jarjoura, Masbki, Taanayel), food processing plants (e.g. Kassatly Chtoura), water bottling industry (e.g. El Rim), wineries, paper industries (e.g. MEMOSA), dyeing and tanning, electroplating, manufacturing of batteries, chemicals, sponge, food packaging materials *etc*. Industrial wastewater from these sources is directly discharged into the river, or is disposed into the city/village sanitary sewer that outflows into the river (figures 20-23).

Figure 20: Berdawni River Tributary in Zahle

Figure 21: Chtaura Water Spring

Figure 22: Anjar Spring

Figure 23: Faour Tributary

Additionally, this zone is known for its restaurants and hotels mainly in Chtoura, Zahle and Anjar (located directly along the river or its tributaries). These sites "mostly" dispose sewage and dump solid wastes directly into the water. The detailed description of the profiles of cities/villages within the orange zone of ULB is presented in appendices. Additionally, the identified point and non point sources of pollution and the selected sampling sites (river water, springs, wells, domestic and industrial wastewater effluents, soil and sediments) are presented in appendices.

5.1.3. THE GREEN ZONE (LOWER ZONE OF THE URB)

This lower region of the Upper Litani Basin is mainly characterized by mixed residential, agricultural, and to a lesser extent industrial and recreational (Qaraoun lake area) activities, and aquaculture farming of trout fish. The river starts with minimal water flow that supports extensive algae growth and the presence of fish, water snakes, and turtles, ducks etc. It then flows into the Qaraoun Lake with relatively more water input due to the feeding of major water springs and the three tributaries of Habasiyeh, Hafir and Jair. Still, the major dependence is on the abundant number of water springs, as the indicated tributaries are almost dry in summer, or completely tapped for irrigation.

The management of municipal solid is still deficient. As for the management of domestic wastewater (sewage), sanitary sewer systems (mostly) and cesspools (minimally) are the main venues of disposal. Currently, a major sewage treatment plant in Jeb Janine is under construction. This plant is projected to treat (secondary/ biological treatment) sewage from 19 villages. Another sewage treatment plant by the Qaraoun Lake, in Bab El Merea, is also under construction (treatment of sewage from Saghbine).

Agricultural activities in this zone mostly relate to fruit trees (mainly vineyards). Agricultural lands are mostly dependent on Irrigation Canal 900 that directs water from the Qaraoun Lake, across Baaloul, Lala, Jeb Jenine and Kamed Al Louze.

Moreover, this zone is characterised by minimal industrial activities, such as sugar cane industries, car repair shops, paper industries (e.g. SICOMO), dyeing and tanning, The industrial wastewater effluents discharge, mostly, into the river either directly or through the city/village sanitary sewer that outflows into the river. Additionally, this zone is known for its restaurants and hotels mainly in the Qaraoun Area. As such, this zone is the major contributor to the Litani river flow and to the Quaoun Lake during the dry season. Additionally, ground water sources in the area also support domestic water projects (e.g. Luci wells and the blue project on Ain El Tout in Baaloul).

Figure 24: SICOMO Wastewater Discharge

Figure 25: Litani River in Mansoura

Figure 27: Khrayzat Spring

Figure 26: Wastewater Discharge in Ghazza

The detailed description of the profiles of cities/villages within the green zone of ULB is presented in appendices. Also, the identified point and non point sources of pollution and the selected sampling sites (river water, springs, wells, domestic and industrial wastewater effluents, soil and sediments) are presented in appendices.

5.2. LITANI RIVER WATER QUALITY ASSESSMENT

Among the 50 sampling sites (along the Litani river and its tributaries), identified by the reconnaissance survey, 24 sites (48%) were found dry (Figure 5). Additionally, minimal water flow was observed along the river and its tributaries, as the water springs and resulting river tributaries are almost "completely" tapped for irrigation or are dry (Jeb El Habash, Faour and Jdeita water springs).

Moreover, as indicated before, even sewage and industrial wastewater effluents (normally discharging into the water body) are being tapped and used for irrigation. This makes it difficult to locate the sanitary sewer discharge points along the river and its tributaries.

Reflecting on the levels of dissolved oxygen (a major factor that determines ecological viability and self purification capacity of a water body) the contamination profile becomes evident. The mean levels of oxygen in water samples is 4.65 mg/l with a maximum level of 9.4 mg/l and a minimum level 0.38 mg/l and a standard deviation of 2.7 mg/l. Levels of oxygen dropped to less than 5mg/l (needed to support aquatic life) in about 46% of the sampled sites despite the excessive growth of algae along the lower (green), and middle (orange) zones of the ULB. In comparison, the dissolved oxygen reported by the BAMAS 2005 study was 5.93 mg/l.

Furthermore, the drop in oxygen levels along the river and its tributaries is concurrent with the increased biological oxygen demand (BOD), as presented in figures 28-29, and appendices. The mean reported BOD level is 548 mg/l (maximum level: 2530 mg/l; minimum level 2.5 mg/l) with a standard deviation of 768 mg/l.

Although there is no set guideline level for BOD, (Lebanese Standards, Environmental protection Agency [EPA] Standards, and the World Health Organization [WHO] Guidelines) still, surface waters with minimal exposure to organic contaminants are expected to have low BODs of less than 30mg/l. Evaluating BOD levels based on this recommended level, about 62% of the sampled sites have higher biochemical oxygen demands. Such existing high levels are a direct reflection of exposure to organic sources of pollution such as domestic wastewater (sewage), municipal solid waste dump sites, food processing plants wastewater discharge, specific types of industrial wastewater effluents (e.g. paper mills) and agricultural runoff.

This assumption is verified by reflecting on the point and nonpoint sources of pollution corresponding to the areas of Hezzine, Ferzol, Ablah, Jdeita, Al Marj, Taanayel, Ammiq, Dier Zanoun, and Jeb Janine as presented in table 2.

However, It is to be noted that the location of sanitary sewer outlets is not restricted to the cities and villages cited in table 2, as such outlet are located throughout the main river and its tributaries. However, since "mostly" sewage is tapped for irrigation, these discharge outlets are dry, and as such could not be identified.

Moreover, comparing the prevailing BOD levels, with levels reported by the BAMAS 2005 study, shows that the mean BOD levels increased from 48 to 548 mg/l; that is about 11 folds. This further confirms the exposure to the indicated sources of pollution; whether sewage or industrial wastewater discharge. However, it is to be noted that although lots of efforts have been invested to increase the coverage of sanitary sewer systems still, wastewater is mostly discharged into the river and its tributaries without prior treatment, as will be discussed further on.

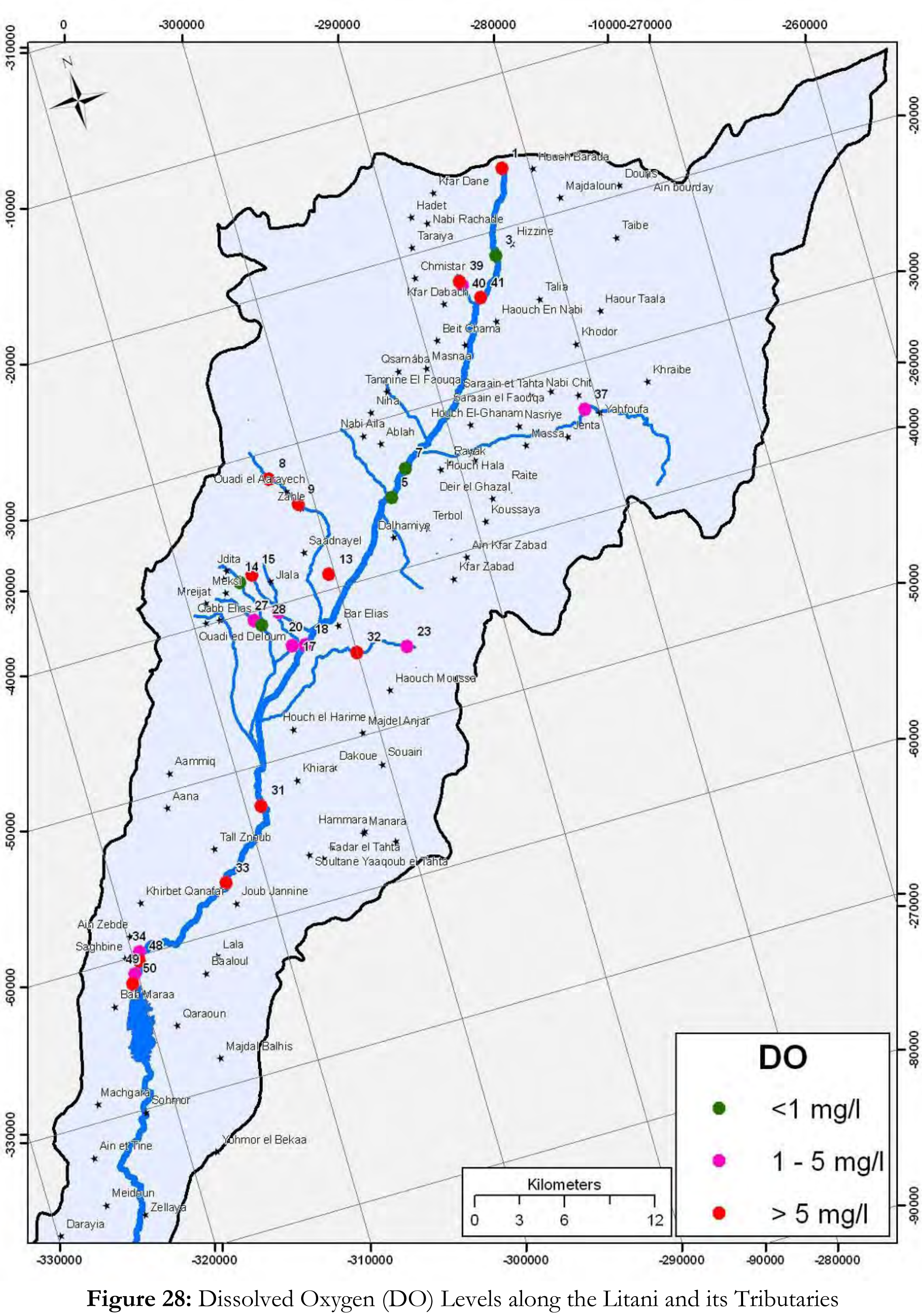


Figure 28: Dissolved Oxygen (DO) Levels along the Litani and its Tributaries

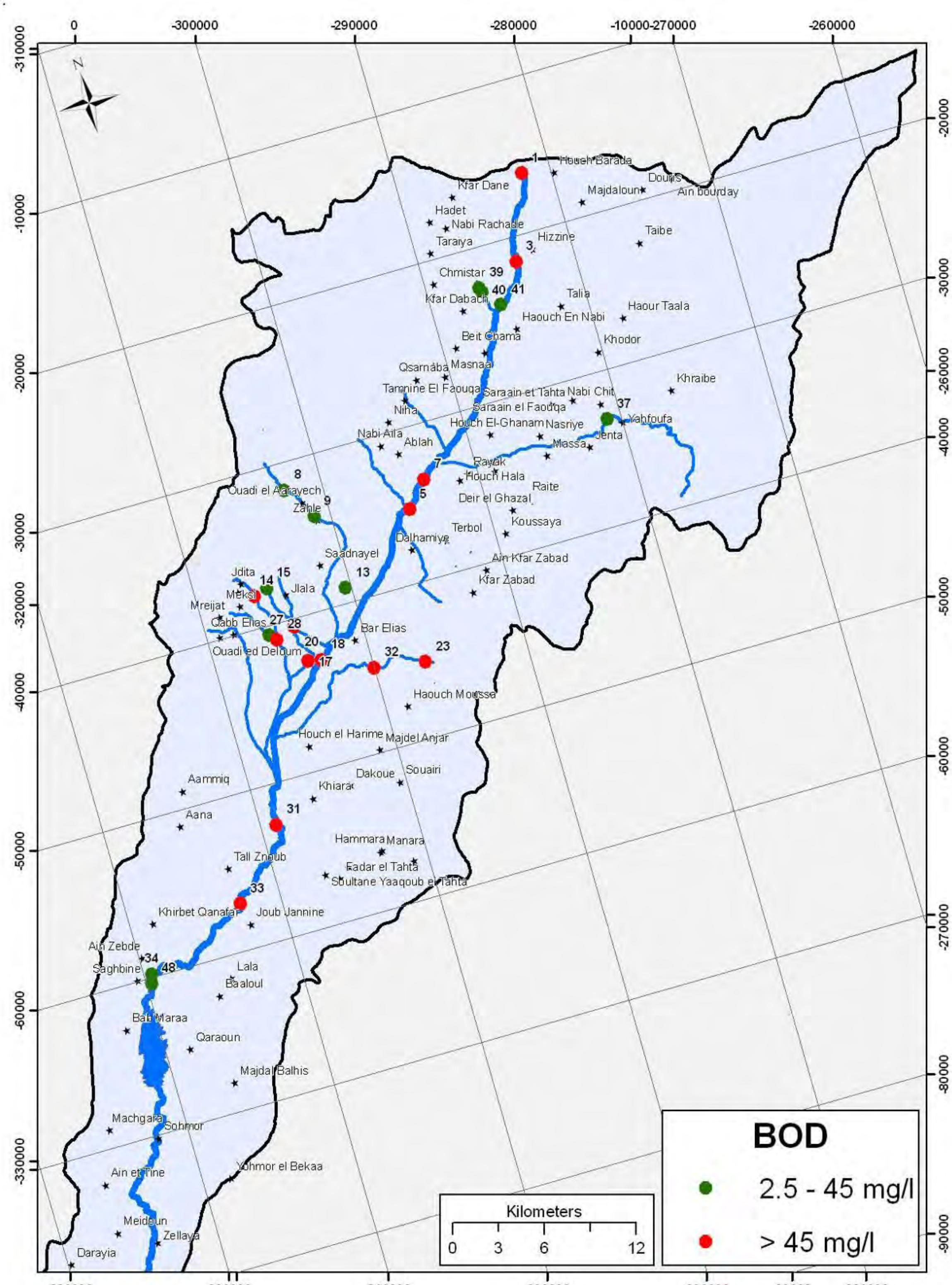


Figure 29: Biochemical Oxyegn Demand (BOD) Levels along the litani and its Tributaries

Table 2: Major Point and Nonpoint Sources of Organic Types of Contaminants

City / Village	Point Sources of Pollution	Non-Point Sources of Pollution
Hezzine	-Domestic Wastewater (Sewage) -Dump Site for Solid Wastes	Agricultural Runoff
Ferzol	-Industrial Wastewater(e.g. Master potato Chips) - Secondary Treated Wastewater Effluent -Solid Waste Dump by the river	Agricultural Runoff
Ablah	-Industrial Wastewater (Poultry Processing Plant {e.g. Tanmeiyah}) -Domestic Wastewater (Wastewater treatment plant under construction) -Solid Waste Dump adjacent to the River	Agricultural Runoff
Jdeita	-Industrial wastewater (Dairy Plants {e.g. Jarjoura} , Serum Industry and Paper Mills)	Agricultural Runoff
Al Marj	-Solid Waste "landfill"	Agricultural Runoff
Taanayel	-Industrial Wastewater (e.g. Taanayel Dairy Plant)	Agricultural Runoff
Ammiq	-Industrial Wastewater (e.g. SICOMO Industry)	Agricultural Runoff
Dier Zanoun	-Domestic Wastewater (Anjar & Majd Al Anjar)	Agricultural Runoff
Jeb Janine	-Domestic Wastewater(Jeb Janine & Kamed Al Louze) as the wastewater treatment plant is still under construction	Agricultural Runoff

Per se, the ecological viability and the self purification capacity of this vital water resource are continuously and progressively challenged by increased contamination loads associated, mostly, with the improper direct disposal of wastewater along the river and its tributaries.
Moreover, when evaluating the physical, chemical and microbiological water quality profile of the river and its tributaries (URB) for multipurpose usage, the following can be concluded:

5.2.1. DOMESTIC WATER USE

Evaluating the quality of surface water for possible domestic water use shows an overall mean mineral content of 503 mg/l with a maximum level of 1979 mg/l and minimum level of 187 mg/l and a standard deviation of 429 mg/l, as presented in table 3 and appendices. This mean level of TDS is acceptable when compared to the Lebanese Standards, EPA Standards and WHO Guidelines recommended levels. Still, about 23% of the sampled sites exceed the recommended Lebanese and EPA standard levels as presented in Tables 3 - 4.

The high TDS levels reflect on the presence of inorganic salts such as calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates in addition to small amounts of organic matter, may be objectionable to consumers (WHO, 2008). TDS levels in water usually originate from natural sources such as rocks, bedrocks, soil, plankton, and silt, seawater intrusion, sewage, urban runoff and industrial wastewater (UNESCO/WHO/UNEP, 1996; WHO, 2008). At TDS levels lower than 600 mg/l, the taste of water is acceptable; however, it may become significantly unpalatable for consumers at levels exceeding 1000 mg/l (WHO, 2008). On the other hand, TDS levels greater than 1200 mg/l are associated with excessive scaling in water pipes, heaters, boilers and household appliances (WHO, 2006), Still, No direct health hazards are associated with the ingestion of water containing high levels of TDS (WHO, 2008). However, their presence may be associated with irritation of the gastrointestinal tract (WHO, 2006).

Comparing to the results reported by the BAMAS 2005 study (mean TDS level of 290 mg/l) shows an increase in the overall mineral content from 290 mg/l to 503 mg/l (1.7 folds). This is mostly reflective of increased exposure to contamination loads (despite efforts to increase sewerage coverage, sewer outflows discharge along the river and its tributaries).

As for the pH of the water samples the mean value is 7.93 (maximum level: 8.66; minimum level 7.27) with a standard deviation of 0.37. Although elevated pH levels have no direct health impact, it is considered an important water quality parameter that should be accounted for when treating the water source; especially when disinfecting by chlorination. The water pH should be less than 8 for optimal disinfection (UNESCO/WHO/UNEP, 1996; WHO, 2008). Additionally, the pH values of all sampled sites were within the acceptable range of 6.5-8.5.

Table 3: Percentage of Surface water Sampling Sites Exceeding Recommended National and International Standard Levels for Drinking Water

Water Quality Parameter	BAMAS Study 2005 %	Current Study 2010 %
Total Dissolved Solids	16	23
Ammonia	87	100
Nitrates	8	None
Phosphate	68	69
Sulfates	None	None
Manganese	NA*	42
Cadmium	NA	45
Fecal Coliform Count	100	50

*Not Availble

Still, the increase of the pH towards alkalinity is a major reflection of exposure to soures of pollution such as sewage, leachate of solid waste dumps and food processing plants' effluents. Comparing to the pH levels reported by BAMAS 2005 study, the increase in the pH mean level from 7.09 to 7.93, is a clear indication of exposure to such sources of pollution.

Moreover, the mean high levels of ammonia in sampled sites is about 11.85 mg/l as ammonia N (maximum level: 68.5 mg/l; minimum level 0.08 mg/l) with a standard deviation of 19.19 mg/l (Table 3) and is reflective of sewage pollution especially under conditions of reduced oxygen levels, as discussed before. No Health specific standard/guideline level is recommended by EPA or WHO. However, the National standards recommend that the level of ammonia should not exceed 0.05 mg/l. Still, all the sampled sites (100%) exceed this level. In comparison the BAMAS 2005 study results reflect on a mean level of 12.30 mg/l and non-conformity of 87% of the sampled sites, as presented in tables 3 - 4.

Table 4: Comparison of the Surface Water Quality Profile Reported by the BAMAS 2005 Study and the Current Study 2010 determined Water Quality Profile.

Indicator	BAMAS 2005* (Calculated from Surface Water Results)			Current Study 2010 Surface Water Results			Drinking Water Standards			Reclaimed WW for Irrigation
							MoE-Lebanon		US EPA	
	Min	Mean	Max.	Min.	Mean	Max.	GV[1] (20 °C)	GV[1] (25 °C)	GV/MAL[2]	MoE Guidelines
T (°C)	12	20.07	25	15.50	23.73	32.10	12	NA[4]	NA	
TDS (mg/l)	88	290.96	706	187.00	502.08	1979	400[5]	500[6]	500[6]	
pH	6.57	7.09	7.68	7.27	7.93	8.66	6.5-8.5	6.5-8.5	6.5-8.5	
DO (mg/l O_2)	0	5.93	8	0.38	4.65	9.40	NA	NA	NA	
BOD (mg/l)	2	48.46	624	2.50	547.65	2530	NA	NA	NA	10-45
NH_4 [7] (mg/l)	0	12.31	120	0.10	15.26	88.22	0.05	NA	NA	
NO_3^- (mg/l)	3	13.46	62	0.10	1.23	4.90	25	10 (as N)	10 (as N)	
SO_4^{2-} (mg/l)	4	21.26	225	1.00	23.48	90.00	25	250	250	
P_2O_5 [10] (mg/l)	0	11.75	197	0.00	8.58	72.44	0.4	NA	NA	
FC (CFU[9]/ 100,ml)	0	223,487	15,0000	1	71.61	>400	0	0	0	5-2,000

[1] GV: Guideline value

[2] MAL: Maximum admissible level ; USEPA: US Environmental Protection Agency

[3] All values reported < a certain value are set equal to that value when calculating the average

[4] NA: Not applicable

[5] Reference temperature at 20°C

[6] Reference temperature at 25°C

[7] Initial value reported is NH_3 , for comparison a conversion factor of 1.0588 was used ($NH_4 = NH_3*1.0588$)

[8] Initial value reported is o-PO_4^{3-}, for comparison a conversion factor of 0.743 was used (P_2O_5 = o-PO_4^{3-} *0.743)

[9] CFU: colony forming unit

As for the presence of nitrates, levels are not as high as that of ammonia. This is expected under conditions of reduced oxygen content which is not sufficient to oxidize the high ammonia content. The mean levels of nitrates is about 1.2mg/l as nitrate N (maximum level: 4.90 mg/l; minimum level 0.1mg/l) with a standard deviation of 1.2 mg/l. As such, all samples have acceptable nitrate levels of less than 10mg/l as nitrate N (Lebanese Standards, EPA Standards and WHO Guidelines). In comparison, the BAMAS 2005 study results reflect on higher nitrate levels with 8% of the samples exceeding the standard level. High nitrate concentrations are mostly associated with the occurrence of methemoglobinemia (Cyanosis or blue – baby syndrome) in infants and young children. Methemoglobinemia develops when immature infant gut converts nitrates to nitrites which react with hemoglobin to form methemoglobin, so blocking oxygen transport (Afzal, 2006; Rizk, 2009; WHO, 2008).

As for the presence of phosphates in sampled sites, the mean level was 12.01 mg/l as PO_4 (maximum level: 97.50 mg/l as PO_4; minimum level 0.00 mg/l as PO_4) with a standard deviation of 26.58 mg/l as PO_4 (Table 2). This is also reflective of exposure to sewage point sources of pollution. Comparing to the recommended national standard level, about 69% of sampled sites exceed the acceptable limits. This finding is comparable to the 68% non-conformity reported by the BAMAS 2005 study. Orthophosphates, originate from the weathering of phosphorus–bearing rocks and the decomposition of organic matter (UNESCO/WHO/UNEP, 1996). In addition, the presence of high concentrations of phosphates reflects on sources of contaminants such as domestic wastewater (detergents), industrial effluents, and fertilizers (UNESCO/WHO/UNEP, 1996).

As for the levels of sulfates in water, mostly these levels are not as high when associated with sewage discharge. The mean level is 23.5 mg/l with a standard deviation of 19.66 mg/l as SO_4 (maximum level: 90 mg/l as SO_4; minimum level 1.00 mg/l as SO_4) as presented in table 2. This may be attributed, similar to nitrates, to reduced levels of the oxygen in surface water. Concurrently, under minimal levels of oxygen, high levels of H_2S prevail and are associated with the foul smell of sewage.

Still, the mean levels were all below the acceptable limit of 250 mg/l. Sulfate is naturally present in water originating from sedimentary rocks (pyrite or gypsum) and is also contributed anthropogenically from industrial effluents, cesspools infiltrates' and agricultural activities (WHO 2006). Comparing to the BAMAS 2005 study results (mean value of 29 mg/l), confirms the reduced oxygen availability and the prevailing reduced chemical forms. Still levels in both studies were below the recommended Lebanese standard of 250 mg/l as presented in tables 3-4.

Chloride levels for sampled water sites ranged between 15 and 325 mg/l with a mean level of 68 mg/l and a standard deviation of 86 mg/l, as presented in table 3. Additionally, 7.7 % (2 sites) of the sampled sites exceeded the recommended national standards, EPA standards and WHO guidelines (Table 4). This element was not determined in the BAMAS study, as such there is no basis for comparison.

AS for the presence of trace metals in the sampled sites, comparing the levels to the set National and International standards, the main problems related to:

1. Cadmium; levels exceeded in 45% of the sampled sites the National recommended standard of 0.005 mg/l and in 54% of the sampled sites WHO guideline level of 0.003 mg/l,
2. Manganese; levels exceed the national and EPA standard levels of 0.05 mg/l in 42% of the sampled sites, and
3. Barium; levels are building up, with a mean level of 0.273 mg/l in comparison to the national standard level of 0.500 mg/l.

The major sources of cadmium are waste streams, leaching landfills, industrial wastes (batteries, plastics, paints, electroplating), fertilizers and pesticides. And it is associated in man with bone and cardiovascular diseases, liver and nerve damage and cancer (Perfect Life Institute, 2002).

Manganese on the other hand is present in steel and alloys, fertilizers ($MnSO_4$), ceramics, fungicides (MnO_2), dry-cell batteries, fireworks and disinfectants ($KMnO_4$) Exposure to high concentrations over the course of years is associated with toxicity to the nervous system, producing a syndrome that resembles Parkinsonism. This type of effect is more likely to occur in the elderly (Perfect Life Institute, 2002).

As for Barium, the main sources are cement, ceramics, glazes, glass, paper making, pharmaceutical and cosmetic products. The health effects of barium depend upon the water-solubility of the compounds. Barium compounds that dissolve in water can be harmful to human health. The uptake of very large amounts of barium that are water-soluble may cause paralyses and in some cases even death. On the other hand, small amounts of water-soluble barium may cause breathing difficulties, increased blood pressure, heart rhythm changes, stomach irritation and muscle weakness, changes in nerve reflexes, swelling of brain, and liver, kidney and heart damage.
(Perfect Life Institute, 2002).

The "hot spots" with relatively high levels of contaminants are distributed along the river and its tributaries, as presented in table 2. And based on the identified point and nonpoint sources of pollution in the ULB, their presence in water is most properly associated with solid waste dumps, the application of fertilizers and pesticides, industrial wastewater effluents *etc.* As such, this renders water unsuitable for drinking and requires advanced treatment processes to deal with these types of contaminants.

As for the microbiological water quality profile the principal concern in is the health risks posed by fecal contamination as the presence of total coliforms is not a health threat by itself and can be naturally present in water and soil environments (WHO, 2006 and 2008). Contamination by fecal bacteria can cause infection for those who use this water for drinking, preparation of food and personal hygiene (UNESCO/WHO/UNEP, 1996). E. coli, particularly, can cause diseases such as urinary tract infection, bacteraemia, meningitis and diarrhoea that can be mild and non bloody, highly bloody and even fatal, especially in infants and young children. Other symptoms of infection include abdominal cramps, nausea, vomiting and fever (WHO, 2008).

Results of the study (Tables 3-4) show fecal contamination in 50% of the sampled sites and the presence of streptococcus feacalis at one site (3% of sample). In comparison, fecal coliforms were reported in 92% of the tested samples in 2005 (BAMAs 2005). Still, it is important to reflect on specific environmental conditions that may have impacted the presence of fecal organisms in water samples such as the decreased oxygen levels in surface water, as discussed before, and the shallow water film which enhances destruction of fecal organisms by near UVB radiation. These factors can explain the discrepancy between the BOD profile reflecting on high organic loads, as presented before, and the detection of fecal coliforms in surface water (river and its tributaries) sampled sites.

To conclude, sites for possible water extraction for domestic purposes are highly limited due to the minimal water flow, high organic loads, the presence of detected trace metals (cadmium and manganese) and microbiological contamination. Mostly this is associated with direct sewage discharge, scattered solid waste dump sites, industrial wastewater effluents and excessive applications of fertilizers and pesticides.

5.2.2. IRRIGATION WATER USE

The suitability of a water source for irrigation does not only depend on the level of the dissolved solids (salt content) in water but also on the kind of chemical of elements constituting this mineral content. Various soil and cropping problems may develop if the total salt content increases. As such, special management practices may be needed to maintain good crop yields. Additionally, acceptable water quality for irrigation should also be judged on the potential severity of the problems that may result during long-term use (Ayers and Westcot, 1994; Westcot, 1997). The guidelines for evaluating the quality of irrigation water is presented in table 5.

Resulting problems vary both in kind and degree, and are modified by the type and condition of soil, climate and type of crops, as well as by proper skilled management. As a result, there is no set limit on water quality; rather, its suitability for use is determined by the conditions of use that may affect the accumulation of the water constituents and possibly restrict crop yield. The soil problems most commonly encountered and used as a basis to evaluate water quality are those related to salinity, water infiltration rate, toxicity and other miscellaneous problems. As such, assessing the suitability of the quality of the sampled surface water (ULB) for irrigation purposes is evaluated based on international guidelines and standards as presented in table 5, and will relates mostly to the following issues and concerns (Ayers and Westcot, 1994; Westcot, 1997)

- Water salinity
- Water infiltration rate
- Crop toxicity

5.2.2.1. WATER SALINITY

This is caused by salt accumulation in the crop root zone to a concentration that causes a loss in yield. Yield reduction results due to the inability of the crop to extract sufficient water from the salty soil solution. This results in water stress, and if conditions persist for a significant period of time will lead to slowing in the plant growth and reduced plant yield. The plant will wilt; become darker bluish-green in color with thicker and waxier leaves.

Proper soil leaching is the key to controlling water the quality-related salinity problem. Over a period of time, salt removal by leaching must equal or exceed the salt additions from the applied water to prevent salt building up to a damaging concentration. The amount of leaching required is dependent upon the quality of the irrigation water and the salinity tolerance of the crop grown (Westcot, 1997).

Table 5: Guidelines for Evaluating Water Quality for Irrigation

Potential Irrigation Problem		**Units**	**Degree of Restriction on Use**		
			None	**Slight to Moderate**	**Severe**
Salinity*(affects crop water availability)*					
	EC_w (or)	**dS/m**	< 0.7	0.7 – 3.0	> 3.0
	TDS	**mg/l**	< 450	450 – 2000	> 2000

Infiltration ***(affects infiltration rate of water into the soil. Evaluate using EC_w and SAR together)***							
SAR	**= 0 – 3**	**and EC_w**	**=**		> 0.7	0.7 – 0.2	< 0.2
	= 3 – 6		**=**		> 1.2	1.2 – 0.3	< 0.3
	= 6 – 12		**=**		> 1.9	1.9 – 0.5	< 0.5
	= 12 – 20		**=**		> 2.9	2.9 – 1.3	< 1.3
	= 20 – 40		**=**		> 5.0	5.0 – 2.9	< 2.9
Specific Ion Toxicity ***(affects sensitive crops)***							
	Sodium (Na)						
	surface irrigation			**SAR**	< 3	3 – 9	> 9
	sprinkler irrigation			**mg/l**	< 70	>70	
	Chloride (Cl)						
	surface irrigation			**mg/l**	< 140	140 – 350	> 350
	sprinkler irrigation			**mg/l**	< 100	> 100	
	Boron (B)			**mg/l**	< 0.7	0.7 – 3.0	> 3.0
	Trace Elements (see Table 21)						
Miscellaneous Effects ***(affects susceptible crops)***							
	Nitrogen (NO_3 - N)			**mg/l**	< 5	5 – 30	> 30
	Bicarbonate (HCO_3)						
	(overhead sprinkling only)			**mg/l**	< 90	90-500	> 500
	pH				Normal Range 6.5 – 8.4		
	Residual Chlorine			**mg/l**	<1.0	1.0-5.0	>5.0

Source: Adapted from Ayers and Westcot 1994

The total dissolved solid content and the water electrical conductivity are two major indicators used to determine the suitability of irrigation water. In reference to the levels of total dissolved solids (TDS) associated with restriction on water use (<450 mg/l none; 450-2000 mg/l slight to moderate, and >2000 umhos/cm severe), results show that only 23% of sampled sites fall within the slight to moderate category of restriction on use for irrigation as presented in figure 30.

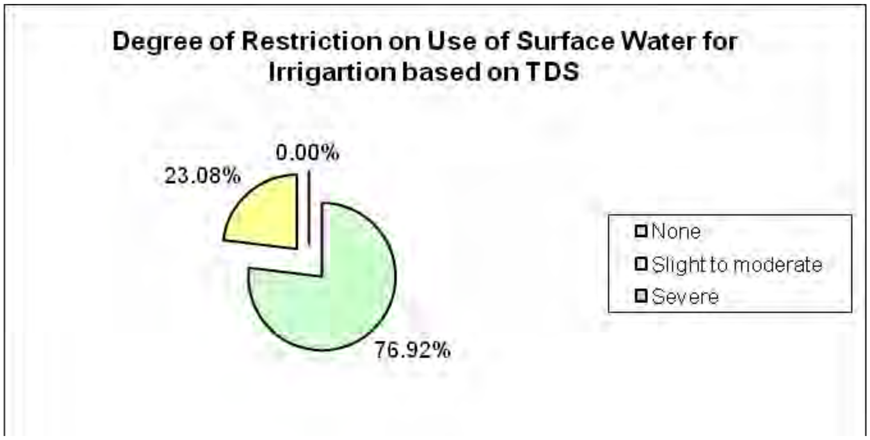


Figure 30: Degree of Restriction on Surface Water Use for Irrigation Based on the Total Dissolved Solids (TDS) Content

5.2.2.2. WATER INFILTRATION RATE

Water infiltration problems occur when irrigation water remains at the soil surface too long, or infiltrates too slowly to provide the crop with sufficient amounts of water to maintain acceptable yields. The infiltration rate of water depends on the quality of the irrigation water, organic load and chemical content (sodium relative to the calcium and magnesium), and it is also impacted by soil characteristics (e.g. structure, degree of compaction (WHO 2006).

The most important quality indicators used to evaluate the water infiltration rate are the water salinity and the sodium content relative to the calcium and magnesium levels (sodium adsorption ratio). The Sodium adsorption ratio (SAR) is computed in the following manner:

$$SAR = \frac{[Na^{+}]}{\sqrt{\frac{([Ca^{2+}]+[Mg^{2+}])}{2}}}$$

where [ ] represents the concentration of cation in cmol(+)/L
note halving sum of $[Ca^{2+}]$ and $[Mg^{2+}]$ before taking square root

As such, low salinity water or water with high sodium to calcium ratio will decrease infiltration. Additionally, when both factors operate at the same time added problems, especially if irrigation time is prolonged to achieve adequate infiltration, can result. Such problems relate to crusting of seedbeds, excessive weeds, nutritional disorders and drowning of the crop, rotting of seeds, lack of aeration, and plant and root diseases. Additionally, among the serious side effects of infiltration is the potential to develop disease and vector (mosquito) problems (Ayers and Westcot, 1994; Westcot, 1997)

Evaluating the quality of surface water based of these two restrictive factors (water salinity and sodium adsorption ratio), results of the study show that about 81% of the sampled sites fall within the slight to moderate category of restriction on surface water use for irrigation (Figure 31).

5.2.2.3. PLANT TOXICITY

Toxicity problems occur if certain constituents (ions) in the soil or water are taken up by the plant and accumulate to concentrations high enough to cause crop damage or reduced yields. The degree of damage depends on the uptake and the crop sensitivity.

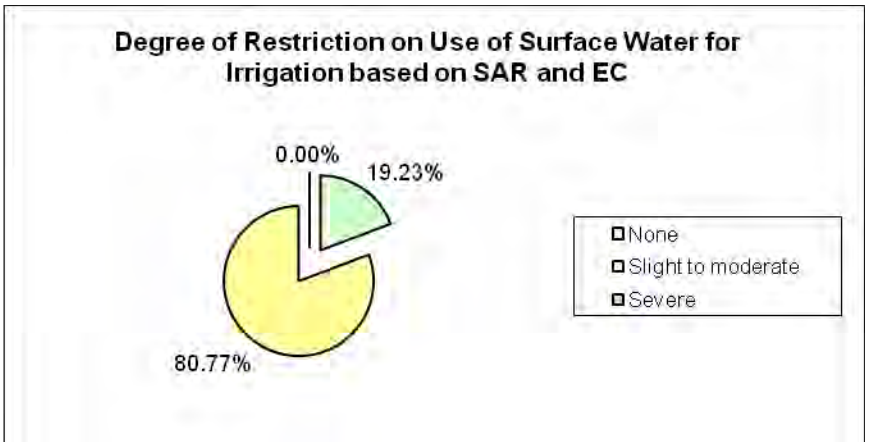


Figure 31: Degree of Restriction on Surface Water Use for Irrigation Based on EC and SAR Levels

The permanent, perennial-type crops (tree crops) are the more sensitive. Damage often occurs at relatively low ion concentrations for crops. It is usually first spotted by marginal leaf burn and interveinal chlorosis. Additionally, if the level of accumulation is high enough, reduced yields result. The more tolerant annual crops are not sensitive at low concentrations but almost all crops will be damaged or killed if concentrations are sufficiently high (Ayers and Westcot, 1994; Westcot, 1997).

The ions of major concern are chloride, sodium, boron and selective trace metals (Table 5). Toxicity problems may occur even when these ions are in low concentrations, and it often accompanies and complicates salinity or water infiltration problems. The ions accumulate to the greatest extent in the areas where the water loss is greatest; usually the leaf tips and leaf edges. However, the process is slow and the visual damage is minimal to be noticed.

Still, the degree of damage depends upon the duration of exposure, concentration of the toxic ion, crop sensitivity, and the volume of water transpired by the crop. In a hot climate or hot part of the year, accumulation is more rapid than if the same crop was grown in a cooler climate or cooler season when it might show little or no damage.

In reference to the levels of sodium in water associated with restriction on water use (<70 mg/l minimal; >70 mg/l slight to moderate), results show that less than 4% of sampled surface water fall within the slight to moderate category of restriction on surface water use for irrigation (Figure 32).

As for the level of chlorides, and in reference to levels associated with restriction on water use (<100 mg/l none; >100 mg/l slight to moderate), results show that less than 20% of sampled sites fall within the slight to moderate category of restriction on water use for irrigation as presented in figure 33.

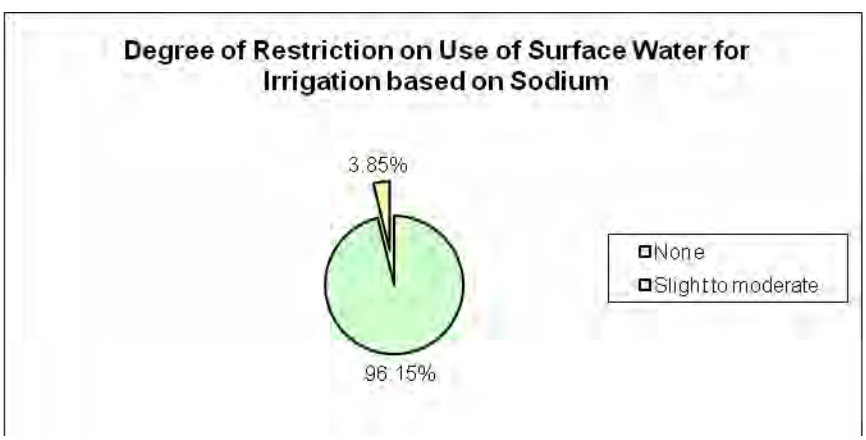


Figure 32: Degree of Restriction on Surface Water Use for Irrigation Based on Sodium Levels

As for Boron, concentrations were below detectable levels to be associated with restrictive surface water use for irrigation. Additionally, based on restrictive water use associated with levels of bicarbonates in water (<90mg/l none; 90-500 mg/l slight to moderate; >500 mg/l severe), results show that the high bicarbonate levels of all samples fall within the slight to moderate restrictive water use category (figure 34). This is mostly due to change in water quality mostly by sewage pollution.

Finally in reference to the presence of toxic trace metals (table 6) results of the study show that the main element of concern, among tested metals, is cadmium. The mean level of cadmium (0.00994 mg/l) is approaching the maximum recommended level of 0.01 mg/l.

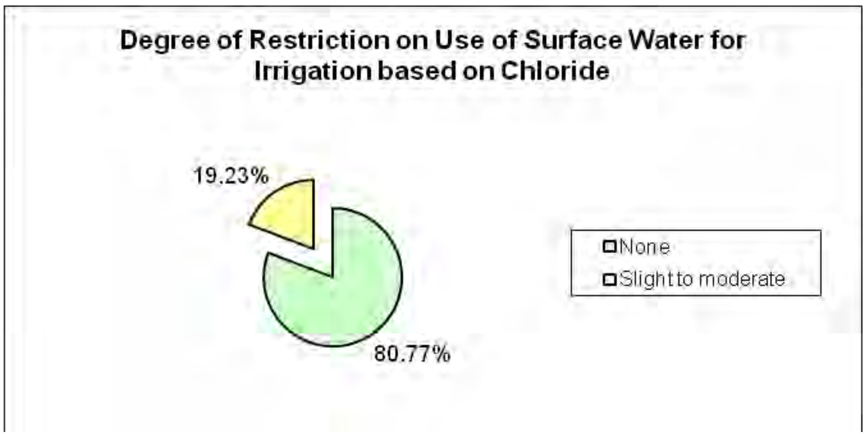


Figure 33: Degree of Restriction on Surface Water Use for Irrigation Based on Chloride Levels

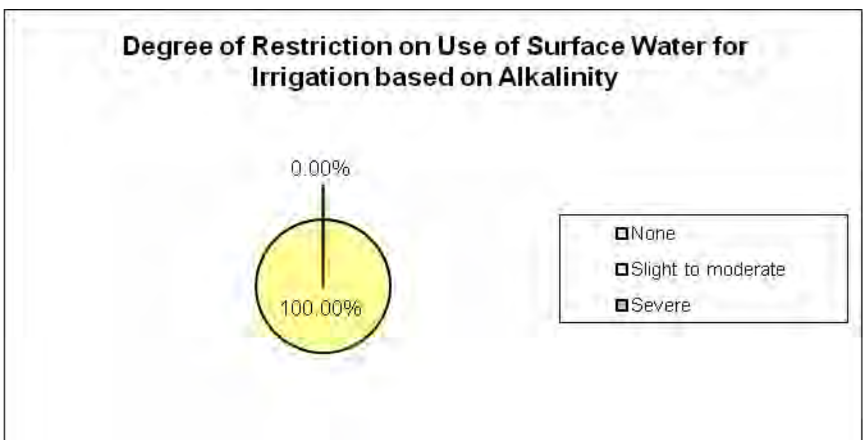


Figure 34: Degree of Restrictive Surface Water Use for Irrigation Based on Bicarbonate Levels

Cadmium is toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits are recommended due to its potential to accumulate in plants and soils to concentrations that may be harmful to humans. As indicated before, the major sources of cadmium are waste streams, leaching of landfills, industrial wastes (batteries, plastics, paints, electroplating), fertilizers and pesticides (WHO 2006).

Table 6: Recommended Maximum Concentrations of Trace Metals in Irrigation Water

Element	Maximum Concentration (mg/l)	Remarks
Al (aluminium)	5.0	Can cause non-productivity in acid soils (pH < 5.5), but more alkaline soils at pH > 7.0 will precipitate the ion and eliminate any toxicity
As (arsenic)	0.10	Toxicity to plants varies widely, ranging from 12 mg/l for Sudan grass to less than 0.05 mg/l for rice.
Be (beryllium)	0.10	Toxicity to plants varies widely, ranging from 5 mg/l for kale to 0.5 mg/l for bush beans.
Cd (cadmium)	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended due to its potential for accumulation in plants and soils to concentrations that may be harmful to humans.
Co (cobalt)	0.05	Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils.
Cr (chromium)	0.10	Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants.
Cu (copper)	0.20	Toxic to a number of plants at 0.1 to 1.0 mg/l in nutrient solutions.
F (fluoride)	1.0	Inactivated by neutral and alkaline soils.
Fe (iron)	5.0	Not toxic to plants in aerated soils, but can contribute to soil acidification and loss of availability of essential phosphorus and molybdenum. Overhead sprinkling may result in unsightly deposits on plants, equipment

		and buildings.
Li (lithium)	2 .5	Tolerated by most crops up to 5 mg/l; mobile in soil. Toxic to citrus at low concentrations (<0.075 mg/l). Acts similarly to boron.
Mn (manganese)	0.20	Toxic to a number of crops at few-tenths to a few mg/l, but usually only in acid soils.
Mo (molybdenum)	0.01	Not toxic to plants at normal concentrations in soil and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum.
Ni (nickel)	0.20	Toxic to a number of plants at 0.5 mg/l to 1.0 mg/l; reduced toxicity at neutral or alkaline pH
Pd (lead)	5.0	Can inhibit plant cell growth at very high concentrations.
Se (selenium)	0.02	Toxic to plants at concentrations as low as 0.025 mg/l and toxic to livestock if forage is grown in soils with relatively high levels of added selenium. An essential element to animals but in very low concentrations.
Ti (titanium)	----	Effectively excluded by plants; specific tolerance unknown.
V (vanadium)	0.10	Toxic to many plants at relatively low concentrations.
Zn (zinc)	2.0	Toxic to many plants at widely varying concentrations; reduced toxicity at pH > 6.0 and in fine textured or organic soils.

Source: Adapted from FAO, 1997

However, it is to be noted that when evaluating the quality of irrigation water (based on acceptable chemical levels that carry no restriction for use), that the guideline levels are based on a number of

assumptions relating to the yield potential of crops, soil conditions enhancing good drainage, and the use of surface or sprinkler methods of irrigation. Moreover, the divisions in "Restriction on Use" entity (none, slight to moderate and high), as presented in table 5, are somewhat arbitrary since change occurs gradually and there is no clear-cut breaking point. "A change of 10 to 20 percent above or below a guideline value has little significance if considered in proper perspective with other factors affecting yield. And values presented are applicable under normal field conditions prevailing in most irrigated areas in the arid and semi-arid regions of the world" (FAO 1997).
As such, when evaluating the suitability of water for irrigation based on the recommended chemical profile, mostly 75% of the sampled sites can be used with no major restrictions (excluding bicarbonate levels that are relatively high due to soil composition, geological formation and indicated sources of pollution) that would impact water salinity, infiltration rates or crop toxicity.

On the other hand, when evaluating water quality based on the microbiological profile of the sampled sites, 61% exceed the recommended limit of 1000/100ml for the total coliform count and 15% exceed the recommended level of 100/100ml for fecal coliforms. Still, as will be discussed later, the residence time of microorganisms in soil and on crops is impacted by factors such as climate conditions, types of soil, availability of irrigation water, proper pest control and implementation of proper management strategies.

On the other hand evaluating the quality of the sampled sites in reference to the proposed National standards (based on BOD levels and fecal coliform counts), results show that sampled sites fall within the maximum limits of class 3 based on the high BOD levels. This is mainly due to the discharge of organic contaminants from the various indicated sources of pollution, as discussed before. On the other hand, reflecting on the levels of fecal organisms in sampled sites, mostly 15% of the sampled sites fall within class 2 to the maximum of class 3. As such, direct irrigation from the river is not recommended. In conclusion, tapping water spring feeding tributaries and water tributaries "completely" for irrigation is destroying the ability of the river and its tributaries to handle the increasingly high loads of contaminants introduced by the various sources of pollution. Controlling such practices is essential to restore the dissolved oxygen levels and to enhance the self purification capacity of this vital water resource and regenerate its quality for multipurpose usage.

5.2.3. WATER FOR LIVESTOCK USE

Water with a high salt may cause physiological upset or even death in livestock. The main reported outcome is depression of appetite, which is usually caused by a water imbalance related to any specific ion. The most common exception is water containing a high level of magnesium which is known to cause scouring and diarrhea (Tables 7-8). As such, and based on the conductivity levels of "almost" all sampled sites (92% of sites), the quality of the river water and its tributaries is suitable for use by livestock.

Table 7: Water Quality Guide for Livestock and Poultry

EC (dS/m)	Rating	Remarks
<1.5	Excellent	Usable for all classes of livestock and poultry.
1.5 – 5.0	Very Satisfactory	Usable for all classes of livestock and poultry. May cause temporary diarrhoea in livestock not accustomed to such water; watery droppings in poultry.
5.0 – 8.0	Satisfactory for Livestock	May cause temporary diarrhoea or be refused at first by animals not accustomed to such water.
	Unfit for Poultry	Often causes watery faeces, increased mortality and decreased growth, especially in turkeys.
8.0 – 11.0	Limited Use for Livestock	Usable with reasonable safety for dairy and beef cattle, sheep, swine and horses. Avoid use for pregnant or lactating animals.
	Unfit for Poultry	Not acceptable for poultry.
11.0 – 16.0	Very Limited Use	Unfit for poultry and probably unfit for swine. Considerable risk in using for pregnant or lactating cows, horses or sheep, or for the young of these species. In general, use should be avoided although older ruminants, horses, poultry and swine may subsist on waters such as these under certain conditions.
>16.0	Not Recommended	Risks with such highly saline water are so great that it cannot be recommended for use under any conditions.

Source: FAO 1997

Additionally, results of the study show that the levels of magnesium in water samples do not exceed 60mg/l with a mean level of 14.8 mg/l and a standard deviation of 11.3 mg/l. Hence, this confirms that the quality of the sampled water along the river and its tributaries is suitable for drinking by all types of Livestock, based on the magnesium water content.

As for the presence of trace metals in livestock drinking water, results show that the levels of the tested trace metals do exceed the recommended levels except for cadmium and manganese (Table 9). This renders the water unsuitable for use.

As such the main rendering factor for surface water use for livestock is neither the high TDS, nor the magnesium levels, but the trace metals water quality profile.

Table 8: Restrictive levels of Magnesium in Drinking Water for Livestock

Type of Livestock	Magnesium Concentration (mg/l)
Poultry	<250
Swine	<250
Horses	250
Cows lactating	250
Ewes with lambs	250
Beef cattle	400
Adult sheep	500

Source: Adapted from FAO 1997

Table 9: Guideline Levels for Trace Metals in Drinking Water for Livestock

Element	Upper Limit (mg/l)
Aluminium (Al)	5.0
Arsenic (As)	0.2
Beryllium (Be)	0.1
Boron (B)	5.0
Cadmium (Cd)	0.05
Chromium (Cr)	1.0

Cobalt (Co)	1.0
Copper (Cu)	0.5
Fluoride (F)	2.0
Lead (Pb)	0.1
Manganese (Mn)	0.05
Mercury (Hg)	0.01
Nitrate + Nitrite (N03-N +NO2-N)	100.0
Nitrite (NO2-N)	10.0
Selenium (Se)	0.05
Vanadium (V)	0.10
Zinc (Zn)	24.0

Source: Adapted from FAO, 1997

5.3. GROUND WATER QUALITY ASSESSMENT

5.3.1. WATER SPRINGS QUALITY ASSESSMENT

A total of 24 major water springs were identified through the field survey of the Upper Litani Basin; 4 springs (15%) of which are dry in summer. The location and GPS coordinates of the sampled water springs are presented in figures 7-8.

Mostly these springs are located in combined domestic, agricultural and to a lesser extent industrial and recreational settings. However, these sources are mostly tapped for irrigation use in summer. Evaluating the physical, chemical and microbiological water quality profile of spring water sources for multipurpose usage, the following can be concluded:

5.3.1.1. DOMESTIC WATER USE

Evaluating the quality of spring water sources for possible domestic water use, results shows an overall mean mineral content of 284 mg/l (maximum level of 396 mg/l; minimum level of 172 mg/l) and a standard deviation of 67 mg/l. This mean level of total dissolved solids is acceptable when compared to the National Standards, EPA Standards and WHO Guidelines recommended levels.

All tested macro-elements and microelements fall within the sets limit values recommended by the National Standards, EPA Standards and WHO Guidelines. The only exception relates to:

- Nitrates; the level in one spring (17 mg/l nitrate N) exceeds the standard level of 10 mg/l as nitrate N. This should be further investigated to identify possible sources of pollution,

- Cadmium; the mean level of cadmium (0.00736 mg/l) exceeds the recommended national standards of 0.005 mg/l b by 1.5 folds,
- Magnesium; the mean level of magnesium (0.07 mg/l) exceeds the recommended guideline level of 0.05 mg/l) by 1.4 folds , and
- Barium; levels are building up, but still below recommended levels.

Moreover the water microbiological quality also limits its potential domestic use. Fecal coliform were detected in 67% of sampled springs, and Streptococcus faecalis in 33% of sampled springs.
As such the quality of spring water sources should be continuously monitored as the impacts of pollution sources are becoming evident. It is crucial to screen all springs used by communities as complementary sources of domestic water in order to determine water safety based on the set Lebanese standards for drinking water.
Additionally, sources used to feed domestic networks should also be continuously monitored. Determination of the levels of trace metals should be an integral component of this quality assessment. Sources exceeding acceptable levels for trace metals should not be used and alternative sources should be immediately identified. As such sources will require advanced treatment, beyond disinfection, to insure water safety.

5.3.1.2. IRRIGATION WATER USE

As discussed before the suitability of a water source for irrigation does not depend only on the level of the total dissolved solids (salt content) in water but on the kind of chemical elements constituting this mineral content. Moreover, acceptable water quality for irrigation should be judged on the potential severity of the problems that may result during long-term use (Ayers and Westcot, 1994; Westcot, 1997). The guidelines for evaluating the quality of irrigation water are presented in table 5.
As such, assessing the suitability of the quality of spring water sources, in the Upper Litani Basin, for irrigation purposes is evaluated based on international guidelines and standards presented in table 5.

5.3.1.2.1. WATER SALINITY

In reference to the levels of total dissolved solids (TDS) associated with restriction on spring water use for irrigation (<450 mg/l none; 450-2000 mg/l slight to moderate, and >2000 umhos/cm severe), results show that all spring water sources can be used for irrigation without any restriction, as presented in figure 35.

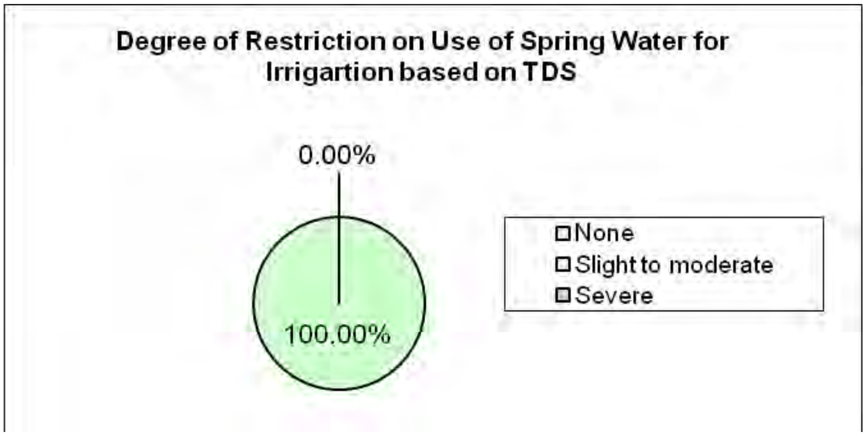


Figure 35: Degree of Restriction on Spring Water Use for Irrigation Based on TDS Content

5.3.1.2.2. WATER INFILTRATION RATE

Evaluating the quality of spring water sources based on EC and SAR, results show that all spring water sources can be used for irrigation without any restriction, as presented in Figure 36.

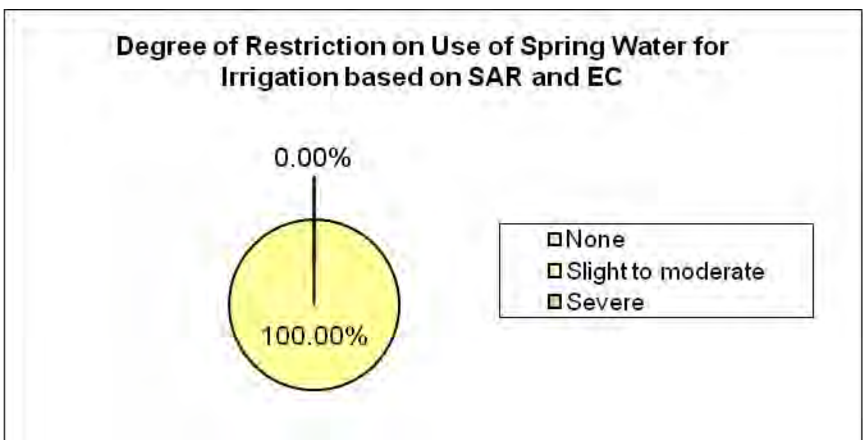


Figure 36: Degree of Restriction on Spring Water Use for Irrigation Based on EC and SAR Levels

5.3.1.2.3. PLANT TOXICITY

As indicated before, the ions of major concern are chloride, sodium and boron and selective trace metals (Table 6). In reference to the levels of sodium in water associated with restrictive water use for irrigation (<70 mg/l minimal; >70 mg/l slight to moderate), results show that all spring water sources can be used for irrigation without any restriction (Figure 37).

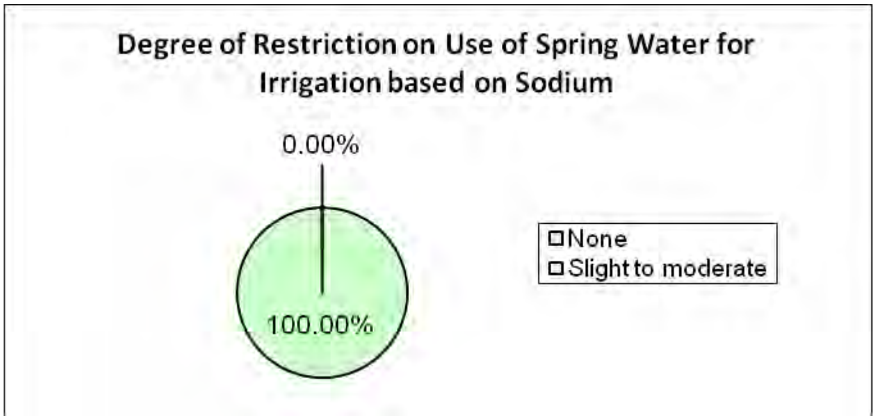


Figure 37: Degree of Restriction on Spring Water Use for Irrigation Based on Sodium Levels

As for the levels of chloride, and in reference to levels associated with restriction on water use for irrigation (<100 mg/l none; >100 mg/l slight to moderate), results show that all spring water sources can be used for irrigation without any restriction as presented in figure 38.

As for Boron, the concentrations are below detectable levels to be associated with any restriction on water use for irrigation. Additionally, based on restriction on water use associated with levels of bicarbonates in water (<90mg/l none; 90-500 mg/l slight to moderate; >500 mg/l severe), results show that the high bicarbonate levels of all samples fall within the slight to moderate restrictive water use category (figure 39).

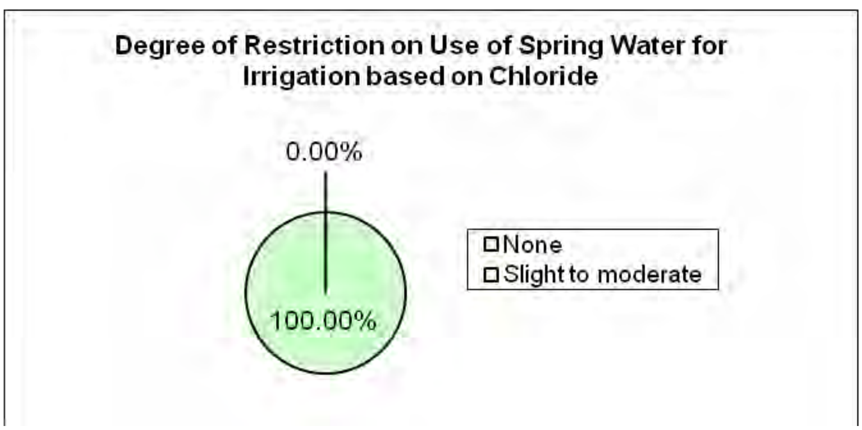


Figure 38: Degree of Restrictive Spring Water Use for Irrigation Based on Chloride Levels

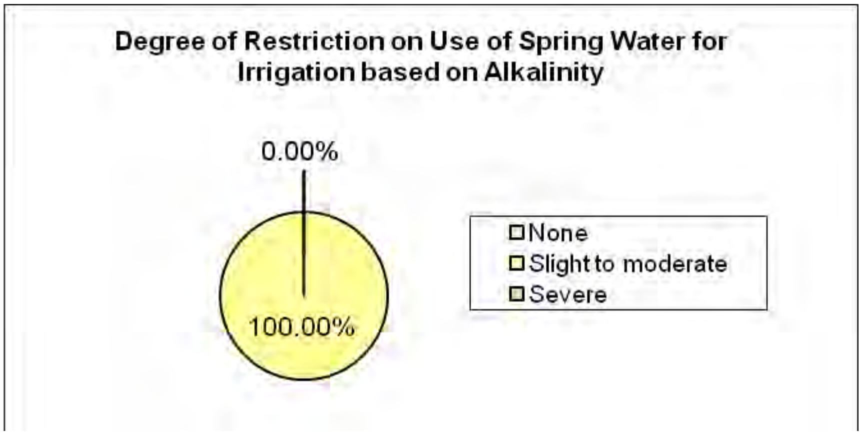


Figure 39: Degree of Restrictive Water Use for Irrigation Based on Bicarbonate Alkalinity Levels

Finally in reference to the presence of toxic trace metals (table 5), results of the study show that the levels of trace metals are not associated with restriction on spring water use for irrigation.

Evaluating the microbiological profile of spring water samples for irrigation use 61% exceeded the recommended limit of 1000/100ml for the total coliform count and 15% exceeded the recommended level of 100/100ml for fecal coliforms. Still, as will be discussed later, the residence time of microorganisms in soil and on crops is impacted by climate conditions, types of soil, availability of irrigation water, the type of crops to be grown, proper pest control, and proper management strategies (Ayers and Westcot, 1994; Westcot, 1997)

5.3.1.3. WATER FOR LIVESTOCK USE

As presented in Tables 7 and 8, and based on the conductivity levels of all sampled sites, the quality of spring water sources is suitable for use by livestock. Additionally, results of the study show that the levels of magnesium in water samples do not exceed 8mg/l with a mean level of 5.10 mg/l and a standard deviation of 1.5 mg/l. As such, the quality of the sampled spring water sources within the Upper Litani basin is suitable for drinking by all types of Livestock.

As for the presence of trace metals in livestock drinking water, results show that the levels of tested trace metals do exceed the recommended levels for cadmium and manganese presented in table 9. This renders the water unsuitable for use. As such the main rendering factor is neither the high TDS, nor magnesium levels, and is mainly reflective of the trace metals water quality profile.

5.3.2. WELL WATER QUALITY ASSESSMENT

A total of 25 accessible wells were identified through the field survey of the Upper litany Basin. The location and GPS coordinates of the sampled wells are presented in figures 7 and 9. Mostly these ground water sources are located in combined domestic and agricultural settings and are "mostly" tapped for domestic water use and for irrigation. Evaluating the physical, chemical and microbiological quality profile for multipurpose usage, the following can be concluded:

5.3.2.1. DOMESTIC WATER USE

Evaluating the quality of well water sources for possible domestic water use, shows an overall mean mineral content of 385 mg/l with maximum level of 863 mg/l and a minimum level of 170 mg/l and a standard deviation of 145 mg/l. This mean level is acceptable when compared to the Lebanese standards (still 12% exceed the standard 500mg/l level), EPA standards and the WHO guidelines recommended levels.

Excluding the levels of nitrates in sampled well water sources, results show that all tested macro-elements and microelements fall within the sets limit values recommended by the National Standards, EPA Standards and WHO Guidelines (Table 10).

Still, high nitrate levels exceeding the recommended 10 mg/l as nitrate nitrogen limit were detected in 20% of the sampled wells in the areas Housh Barada, Hezzine, Sariene, Helanieyeh and Ablah. Concurrently, relatively higher chloride (up to 130 mg/l) and sulfate levels (up to 64mg/l) were also detected at these sites. This is mostly associated with the improper management of sewage.

Moreover the manganese level in one sampling site (Ablah) showed high levels of manganese; 2.7 folds standard level). The well water quality at this site should be further investigated to identify the sources of the contaminant.

Additionally, the presence of total coliform organism was detected in 32% of the samples (in comparison to 78% reported by BAMAS Study 2005), fecal coliforms in 16% of samples (in comparison to 35% reported by BAMAS Study 2005) and Streptococcus feacalis in 8% of the samples.

These findings reflect on efforts to increase the coverage of the sanitary sewer systems. This has reduced on the exposure of ground water aquifers to progressive contamination. Yet, at present, the system is still deficient and sewage outfalls continue to discharge along the water flow without any treatment. Still, the high levels of nitrates are alarming.

Table 10: Percentage of Well Water Sampling Sites Exceeding Recommended National and International Standard Levels for Drinking Water

Water Quality Parameter	BAMAS Study 2005 %	Current Study 2010 %
Phosphates	3	None

Nitrates	70	20
Sulfates	35	None
Fecal Coliforms	78	15

These findings reflect on efforts to increase the coverage of the sanitary sewer systems. This has reduced on the exposure of ground water aquifers to progressive contamination. Yet, at present, the system is still deficient and sewage outfalls continue to discharge along the water flow without any treatment. Still, the high levels of nitrates are alarming.

As such, the quality of well water sources should be continuously monitored as the impacts of pollution sources are evident (e.g. sewage, agriculture run off). It is crucial to screen all wells used by communities as complementary domestic water sources in order to determine water safety based on the set Lebanese standard for drinking water. Additionally, sources used to feed domestic networks should also be continuously monitored. Determination of the levels of nitrates should be an integral component of this quality assessment. Sources exceeding acceptable levels should not be used and alternative sources should be immediately identified.

5.3.2.2. IRRIGATION WATER USE

Assessing the suitability of the quality of spring water in the Upper Litani Basin sources for irrigation based on international guidelines and standards presented in table 5, reflects on the following issues and concerns:

5.3.2.2.1. WATER SALINITY

In reference to the levels of total dissolved solids (TDS) associated with restriction on water use for irrigation (<450 mg/l none; 450-2000 mg/l slight to moderate, and >2000 umhos/cm severe), results show that 24% of sampled wells fall within the slight to moderate restrictive category use for irrigation (Figure 40).

5.3.2.2.2. WATER INFILTRATION RATE

Evaluating the quality of well water sources based on EC and SAR, results show that 70% of sampled wells fall in the category of slight to moderate restrictive well water use for irrigation (Figure 40).

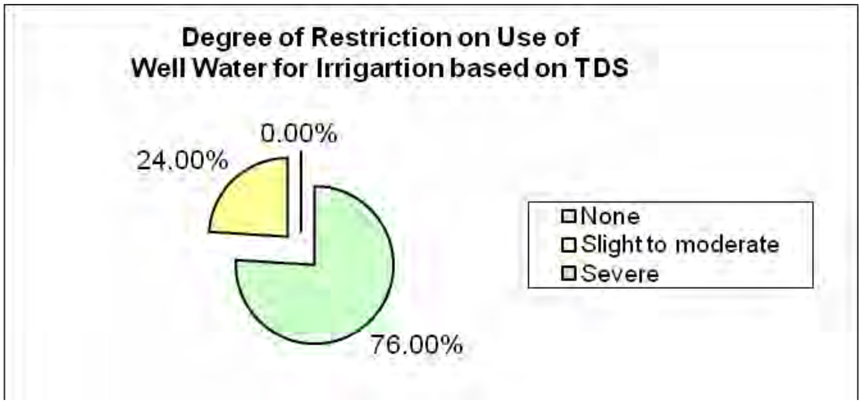


Figure 40: Degree of Restriction on Well Water Use for Irrigation Based on the Total Dissolved Solids

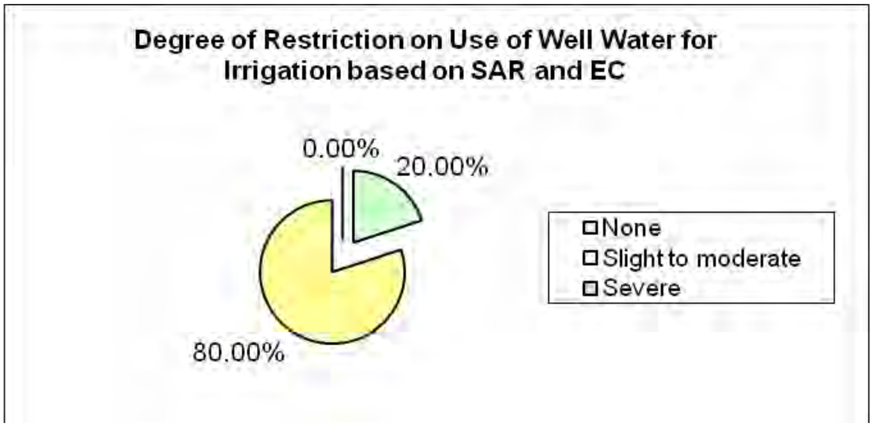


Figure 41: Degree of Restriction on Well Water Use for Irrigation Based on EC and SAR Levels

5.3.2.2.3. PLANT TOXICITY

As indicated before, the ions of major concern are chloride, sodium and boron and selective trace metals (Table 5). In reference to the levels of sodium in water associated with restrictive water use for irrigation (<70 mg/l minimal; >70 mg/l slight to moderate), results show that all wells can be used for irrigation without any restrictions (Figure 42).

As for the levels of chlorides, and in reference to the levels associated with the restriction on water use for irrigation (<100 mg/l none; >100 mg/l slight to moderate), results show that only 4% of sampled wells fall within the slight to moderate restrictive category for irrigation water as presented in figure 43.

Additionally, based on restriction on water use associated with levels of bicarbonates in water (<90mg/l none; 90-500 mg/l slight to moderate; >500 mg/l severe), results show that the high bicarbonate levels of all sampled spring water full within the slight to moderate restrictive water category for irrigation (figure 44). As for Boron, the concentrations were below detectable levels to be associated with restrictive water use.

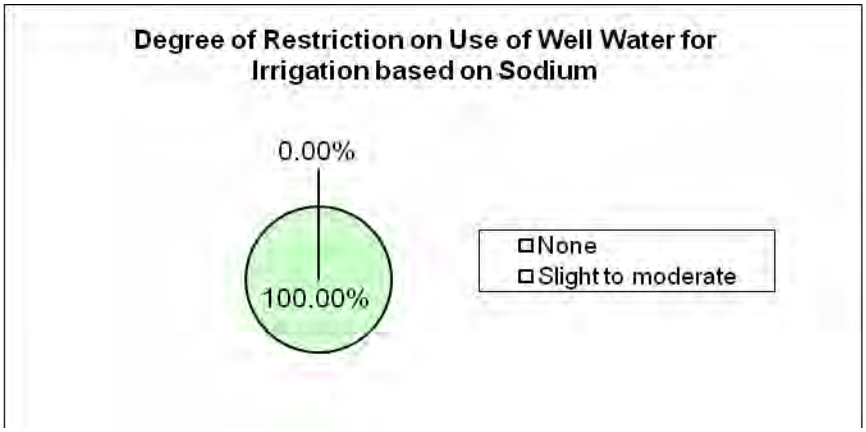


Figure 42: Degree of Restriction on Well Water Use for Irrigation Based on Sodium Levels

Moreover, in reference to the presence of toxic trace metals results show that the levels of trace metals with the exception of one site in Ablah (high levels of manganese; 2.7 folds standard level) are not associated with any restriction on well water use for irrigation. The well water quality at this site should be further investigated to identify contaminants sources.

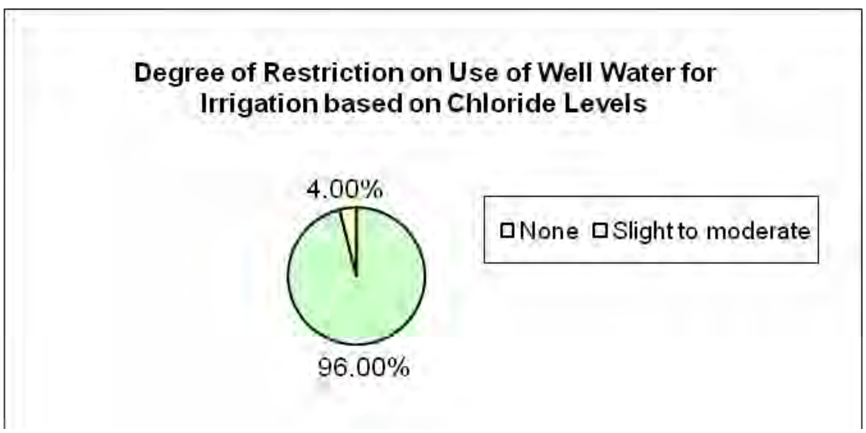


Figure 43: Degree of Restriction on well Water Use for Irrigation Based on Chloride Levels

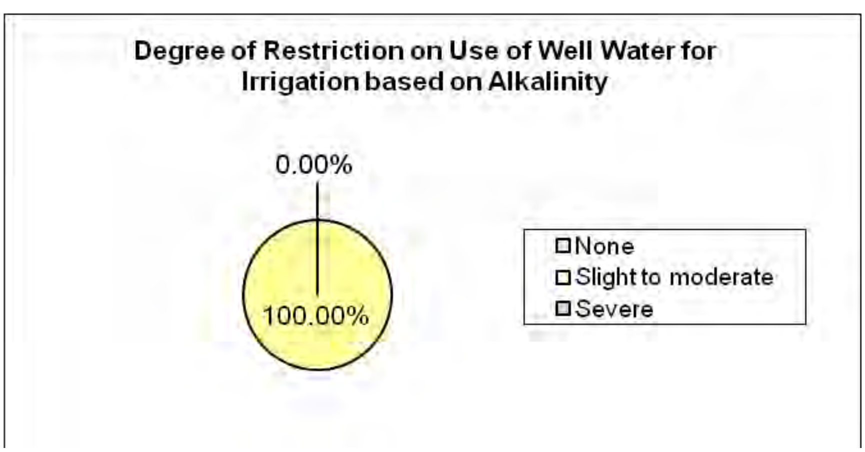


Figure 44: Degree of Restriction on Well Water Use for Irrigation Based on Bicarbonate Alkalinity Levels

Finally, evaluating the microbiological profile for irrigation use, 16% of samples exceeded the recommended limit of 1000/100ml for the total coliform count and 8% exceeded the recommended level of 100/100ml for fecal coliforms. Still, as will be presented later on, the residence time of microorganisms in soil and on crops is impacted by climate conditions, types of soil, availability of irrigation water, the type of crops to be grown, proper pest control and proper management strategies, and should as such be evaluated (Ayers and Westcot, 1994; Westcot, 1997)

5.3.2.3. WATER FOR LIVESTOCK USE

Based on the conductivity levels of all sampled sites, the quality of spring water sources is suitable for livestock (reference to tables 7 and 8). Additionally, results of the study show that the levels of magnesium in water samples do not exceed 85mg/l with a mean level of 16.3 mg/l and a standard deviation of 16.2 mg/l. As such, the quality of the sampled wells, based on the indicated water quality parameters, is suitable for drinking by all types of Livestock.

As for the presence of trace metals in livestock drinking water, results show that the levels of tested trace metals do not exceed the recommended levels presented in table 9 with the exception of one site in Ablah, as mentioned before.

5.4. QARAOUN LAKE WATER QUALITY ASSESSMENT

The overall physico-chemical water quality showed relatively more variability when compared to the results of previous conducted studies (Jurdi et.al, 2001; Korfali et.al, 2006). The total dissolved solids and electrical conductivity however showed minimal variability with time and among the lake zones as presented in table 11.

The pH level, on the other hand, moved towards alkalinity, from a mean level of 7.43 to 8.27, reflecting on progressive exposure to sewage, dump sites leachate and alkaline industrial wastewater effluents such as, dairy plants, paper mills, etc.

As for the biological oxygen demand of water, increased levels reflect on increased exposure to organic contamination loads indicated by the presented sources of pollution. Results show relatively higher BOD in the middle lake zone as presented in figure 46. Concurrently, this impacts the oxidation of the mid-zone leading to reducing conditions. These reducing conditions are reflected by relatively lower nitrates, phosphates, and increasingly higher levels of iron and cadmium from the dissolution of the precipitates of these metals under reducing conditions (Table 11 and figures 45-49).

As for the levels of natural macro-elements (e.g. bicarbonate alkalinity and chlorides), minimal variability is detected in comparison to previously reported findings and among the sampled sites.

Additionally, the levels of cadmium exceeded the recommended National standard level of 0.005 mg/l by 2.1 folds and the higher levels are reported in the mid lake water zone. Manganese levels are increasing with a mean level of 0.04 mg/l compared to the maximum standard limit of 0.05mg/l. Moreover, 30% of the sampled sites exceed this limit level.

As for the profile of the remaining trace metal, all detected levels are below the recommended Lebanese standards and are mostly concentrated in the receiving zone (river inflow into the lake), as presented in figures 50-56

Moreover, comparing the existing physicochemical water profile with that reported by Jurdi et.al (2001) shows that the mid zone (2.5- 3.6 km from receiving zone) that was considered as the "better water extraction zone" for multi-purpose usage (lower organic loads, and higher scavenging of metals in the sediments) is at present a relatively reducing medium (higher organic loads and more solubility of metal sediments). This variability in the water quality makes it difficult to define a better "quality" water zone for possible water extraction.

The most probable explanation to this major finding relates to the disposal of sewage directly by the lake. A wastewater treatment plant located directly by the lake is under construction in Bab Merea (treat domestic wastewater from Saghbine) (Figure 57). For the time being sanitary sewer systems coverage has increased, replacing the point source cesspools. Yet, the sanitary sewer systems are discharging into the lake, awaiting the completion of the treatment plant under construction.

Additionally, another wastewater treatment plant, located directly by the lake is under construction in Saghbine. Meanwhile, collected sewage is also discharged directly into the lake. As such, the delay in "closing the loop"; completing the wastewater treatment plants, and ensuring proper treatment, is boasting the level of organic contaminants in the lake.

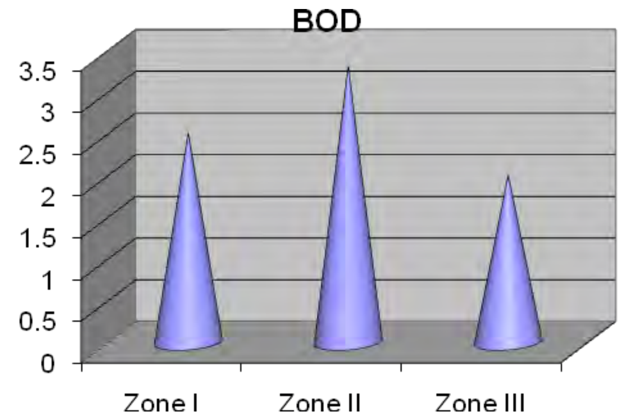


Figure 45: BOD (mg/l) Variability along the Qaraoun Lake

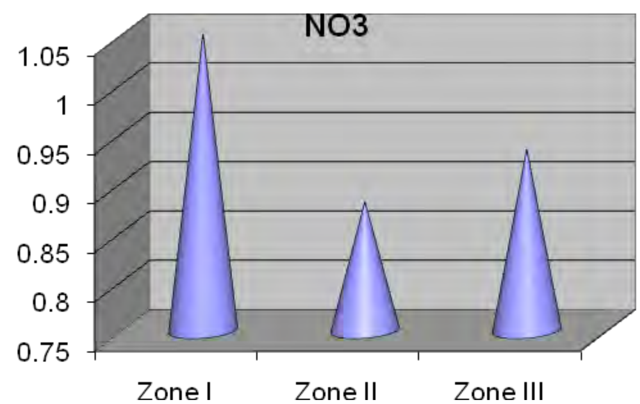


Figure 46: Nitrate (mg/l nitrate N) Variability along the Qaraoun Lake

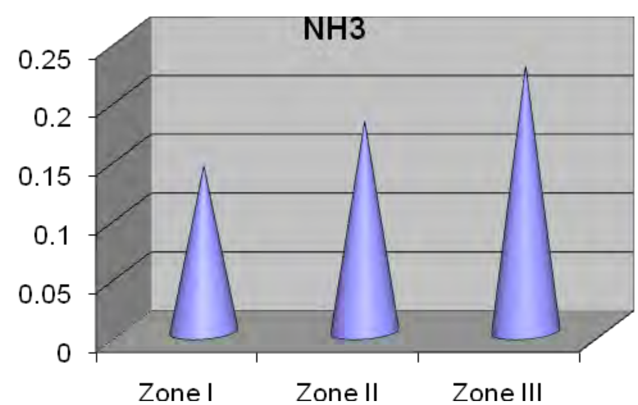


Figure 47: Ammonia (mg/l ammonia N) Variability along the Qaraoun Lake

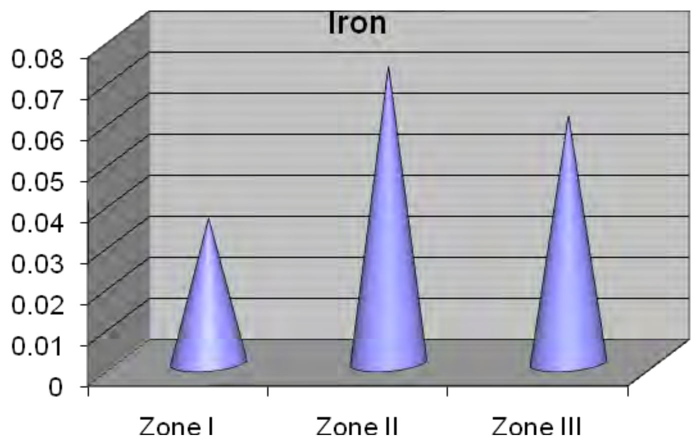


Figure 48: Iron (mg/l) Variability along the Qaraoun Lake

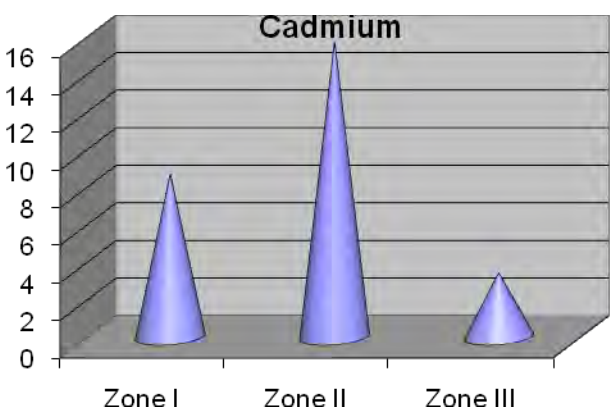


Figure 49: Cadmium (ug/l) Variability along the Qaraoun Lake

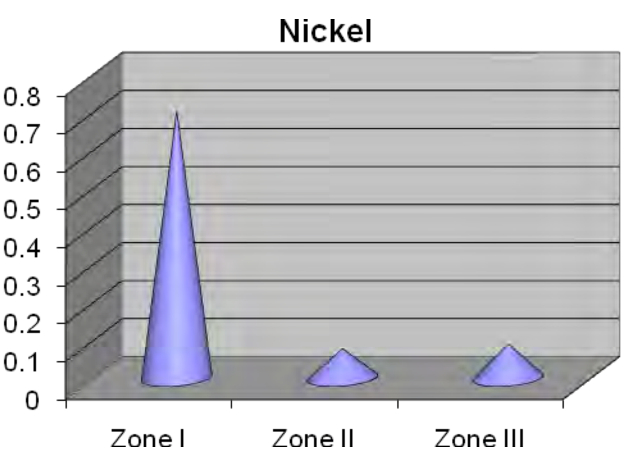


Figure 50: Nickel (ug/l) Variability along the Qaraoun Lake

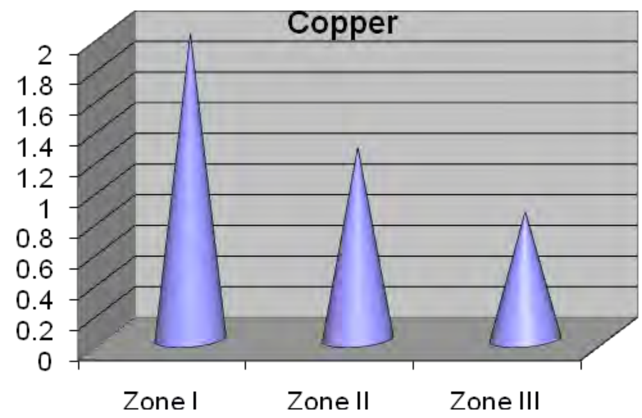


Figure 51: Copper (ug/l) Variability along the Qaraoun Lake

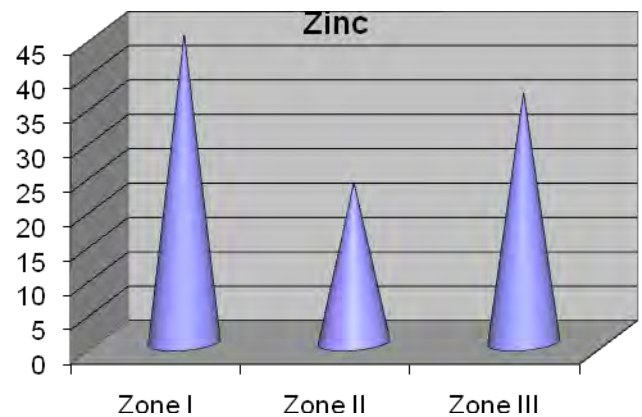


Figure 52: Zinc (ug/l) Variability along the Qaraoun Lake

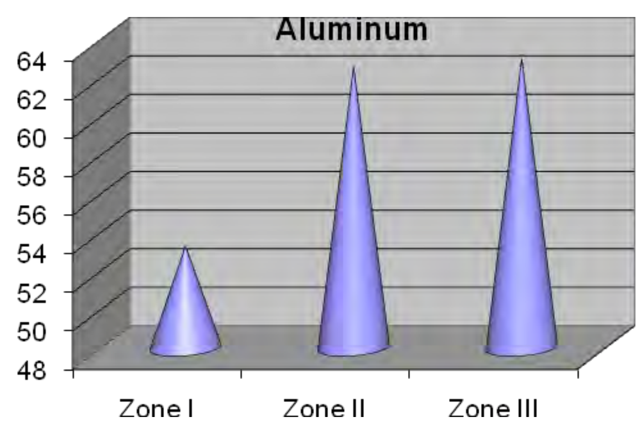


Figure 53: Aluminum (ug/l) Variability along the Qaraoun Lake

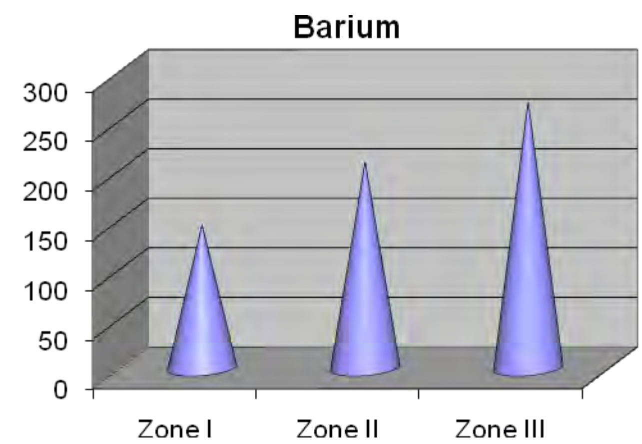


Figure 54: Barium (ug/l) Variability along the Qaraoun Lake

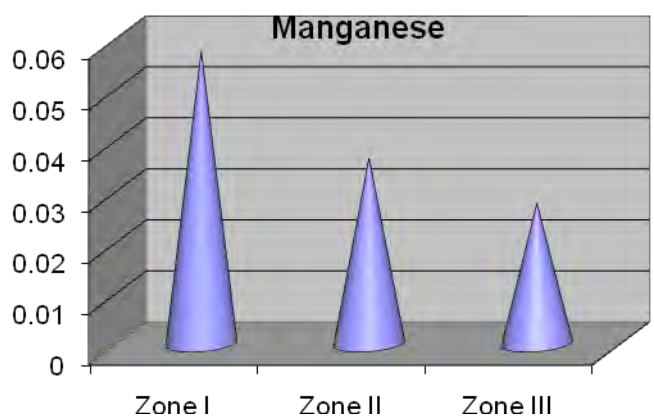


Figure 55: Manganese (mg/l) Variability along the Qaraoun Lake

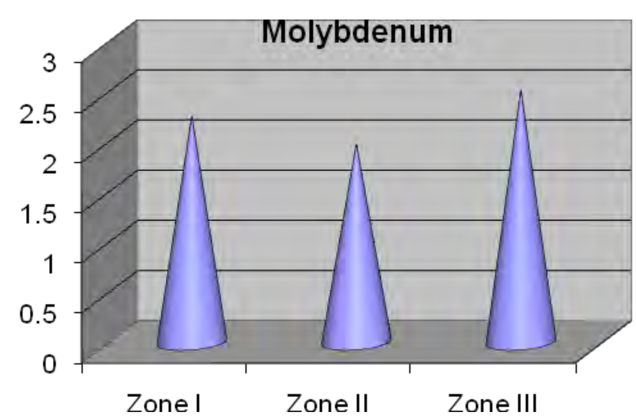


Figure 56: Molybdenum (mg/l) Variability along the Qaraoun Lake

Table 11: Comparison of the Quaaoun lake water Quality profile:BAMAS 2005 and Current Study 2010 (level in mg/l unless indicated)

Indicator	**BAMAS 2005 Calculated from Lake Water Results**			**Study 2010 Lake Water Results**			**National Standards**		
							MoE-Lebanon		**Reclaimed WW for Irrigation**
	Min.	**Mean**	**Max.**	**Min.**	**Mean**	**Max.**	**GV[1] (20 $^{\circ}C$)**	**GV[1] (25$^{\circ}C$)**	**MoE guidelines**
T ($^{\circ}C$)	16.5	20.7	24.8	32.20	33.68	34.70	12	NA[3]	
TDS	120	160	196	221.0	235.0	256.0	400[4]	500[5]	
pH	6.5	7	7.5	8.20	8.27	8.32	6.5-8.5	6.5-8.5	
DO	1.3	3.3	7.7	7.22	8.39	9.41	NA	NA	
BOD	<2	2.57	4	2.00	2.65	3.30	NA	NA	10-45
NH_4[6]	<0.02	0.3	1	0.00	0.20	0.35	0.05	NA	
NO_3^-	62	16.1	21.7	0.80	0.93	1.20	25	10 (as N)	
SO_4^{2-}	25	29.3	33	36.00	37.10	39.00	25	250	
P_2O_5[7]	0.01	0.13	0.35	0.00	0.09	0.245	0.4	NA	
FC (CFU[8]/ 100 ml)	0	17	450	0	160.6	400	0	0	5-2,000

[1] GV: Guideline value

[2] MAL: Maximum admissible level ; USEPA: US Environmental Protection Agency

[3] NA: Not applicable

[4] Reference temperature at 20°C [5] Reference temperature at 25°C

[6] Initial value reported is NH_3 , for comparison a conversion factor of 1.0588 was used (NH_4 = NH_3*1.0588)

[7] Initial value reported is o-PO_4^{3-}, for comparison a conversion factor of 0.743 was used (P_2O_5 = o-PO_4^{3-} *0.743)

[8]CFU: colony forming unit

Figure 57: Wastewater treatment Plant by the Qaraoun Lake in Bab Merae (Under construction)

Comparing the Qaraoun Lake water quality profile with results reported by BAMAS 2005 Study the following can be concluded:

Increase in the levels of total dissolved solids (from 160 to 235; 1.46 folds) reflective on progressive exposure to the various indicated sources of pollution,

Increase in the overall total dissolved oxygen (from 3.30 to 8.39; 2.54 folds), masking the increase in biochemical oxygen demand boasted by organic contaminants. This increase in the levels of dissolved oxygen is mostly reflective of suspended algae growth

Change in pH towards alkalinity (from 7 to 8.27) reflective of exposure to domestic wastewater discharge and industrial wastewater discharge as specified before, Increase in cadmium levels exceeding the recommended National standard level of 0.005 mg/l by 2.1 folds with higher levels detected in the mid lake water zone.

Increase in manganese level to 0.04 mg/l compared to the maximum standard limit of 0.05mg/l. Moreover, 30% of the sampled sites exceed this limit level.

- The presence of remaining trace metals were detected in water samples, but the levels are below the permissible upper limit value (Lebanese standards) and are mostly concentrated in the receiving zone (river inflow into the lake) (Figures 50-56)
- Increased fecal loads (50% of sampled sites are contaminated with fecal organisms)

This change in the quality of the water profile is concurrent with the progressive exposure to contamination loads from the various point and nonpoint sources identified in the Upper Litani Basin.

As for the suitability of the water for irrigation, a detailed presentation of irrigation Canal 900 water quality will follow.

5.5. IIRRIGATION CANAL 900 WATER QUALITY ASSESSMENT

Irrigation Canal 900 provides is designed to deliver 30 million cubic meters per year (m^3/yr) and irrigates approximately 2,000 hectares. The irrigation water is pumped from the Qaroun Lake, flows through the Canal across Baaloul, Lala, Jeb Jenine and Kamed Al Louze.
Comparing to the results of the BAMAS study of 2005 to the results of the current study 2010, as presented in table 12, the main findings reflect on:

- Increase in the levels of total dissolved solids (from 191 to 340; 1.78 folds) reflective of progressive exposure of the Qaraoun Lake to point and nonpoint sources of pollution as presented before,
- Minimal change in the levels of dissolved oxygen despite the progressive growth of algae. This is mostly due to the increase in the biochemical oxygen demand from <2 to 9 mg/l (4.5 folds).
- Change in pH towards alkalinity (from 7.09 to 7.90) reflective of exposure to domestic wastewater discharge, industrial wastewater discharge, etc. as specified before,
- Increase in cadmium levels. The mean level of 0.0103 exceeds the maximum permissible levels in irrigation water (0.01mg/l), and

- Decrease in fecal loads as the irrigation canal is relatively shallow and is not exposed to dire sources of contaminants

This change in the quality of the water profile is concurrent with the progressive exposure of the Qaraoun Lake water to contamination loads from the various point and nonpoint sources identified in the Upper Litani Basin. As such, change in the water quality of the irrigation canal reflects on similar variability in water quality.

Table 12: Comparison of the Quality of Irrigation canal 900; BAMAS 2005 and Current Study 2010 (levels in mg/l unless indicated)

[1] GV: Guideline value

[2] MAL: Maximum admissible level ; USEPA: US Environmental Protection Agency

Indicator	BAMAS 2005 Irrigation canal 900 Water Results			Study 2010 Irrigation Canal 900 Water Results			National Standards		
							MoE-Lebanon		Reclaimed WW for Irrigation
	Min.	Mean	Max.	Min.	Mean	Max.	GV[1] (20 °C)	GV[1] (25°C)	MoE guidelines
T (°C)	15.8	20.63	25.7	20.90	24.41	29.50	12	NA[3]	
TDS	148	191	208	319.00	339.86	363.00	400[4]	500[5]	
pH	6.7	7.09	7.48	7.51	7.71	7.90	6.5-8.5	6.5-8.5	
DO	2	4.84	7.76	1.59	4.94	6.86	NA	NA	
BOD	<2	<2	<2	6.00	9.00	14.00	NA	NA	10-45
NH_4[6]	<0.01	0.49	1.1	0.32	0.58	0.83	0.05	NA	
NO_3^-	11.2	19.75	24.4	0.80	1.39	1.90	25	10 (as N)	
SO_4^{2-}	27	30.45	33	34.00	35.29	37.00	25	250	
P_2O_5[7]	0.01	0.18	0.4	0.17	0.35	0.51	0.4	NA	
FC (CFU[8]/100 ml)	0	241	1200	0	0	0	0	0	5-2,000

[3] NA: Not applicable

[4] Reference temperature at 20°C [5] Reference temperature at 25°C

[6] Initial value reported is NH_3 , for comparison a conversion factor of 1.0588 was used (NH_4 = NH_3*1.0588)

[7] Initial value reported is o-PO_4^{3-}, for comparison a conversion factor of 0.743 was used (P_2O_5 = o-PO_4^{3-} *0.743)

[8]CFU: colony forming unit

As discussed before the acceptable water quality for irrigation is evaluated based on the water mineral content and mineral and projected long term impacts on the quality

5.5.1. WATER FOR IRRIGATION USE

5.5.1.1. WATER SALINITY

In reference to the levels of total dissolved solids (TDS) associated with restrictive water use for irrigation (<450 mg/l none; 450-2000 mg/l slight to moderate, and >2000 umhos/cm severe), results show that Canal 900 water is acceptable for irrigation (Figure 58).

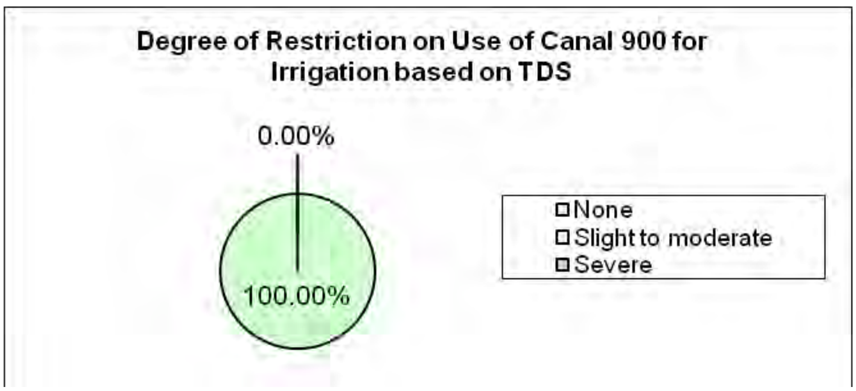


Figure 58: Degree of Restriction on Canal 900 Water Use for Irrigation Based on the Total Mineral Content (TDS)

5.5.1.2. WATER INFILTRATION RATE

Evaluating the quality of Canal 900 irrigation water based of these two restrictive factors (water salinity and sodium adsorption ratio), results show that the canal water falls under the category of slight to moderate restrictive use (Figure 59).

5.5.1.3. PLANT TOXICITY

As indicated before, the ions of major concern are chloride, sodium and boron and selective trace metals (Table 5). The degree of damage depends upon the duration of exposure, concentration of the toxic ion, crop sensitivity, and the volume of water transpired by the crop. In a hot climate or hot part of the year, accumulation is more rapid than if the same crop were grown in a cooler climate or cooler season when it might show little or no damage.

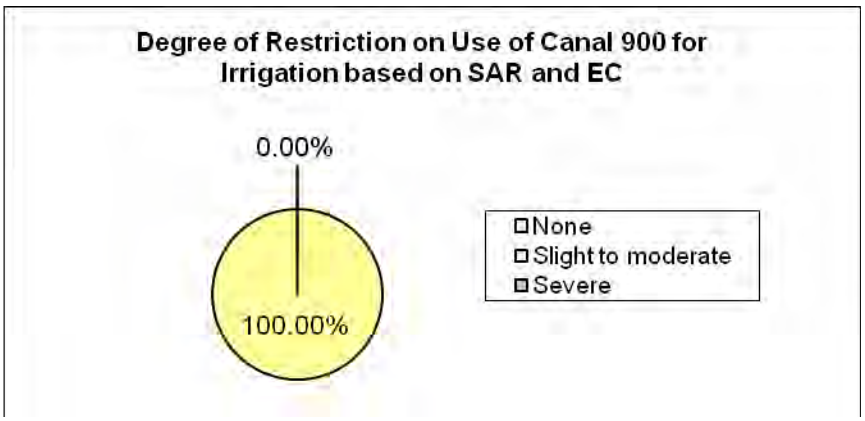


Figure 59: Degree of Restriction on Canal 900 Water Use for Irrigation Based on EC and SAR Levels.

In reference to the levels of sodium in water associated with restrictive water use for irrigation (<70 mg/l minimal; >70 mg/l slight to moderate), results show that Canal 900 water is acceptable for irrigation (Figure 60).

As for the levels of chloride and in reference to limits associated with restrictive water use for irrigation (<100 mg/l none; >100 mg/l slight to moderate), results show that Canal 900 water is acceptable for irrigation as presented in figure 61. As for Boron, the concentrations were below detectable levels to be associated with restrictive water use.

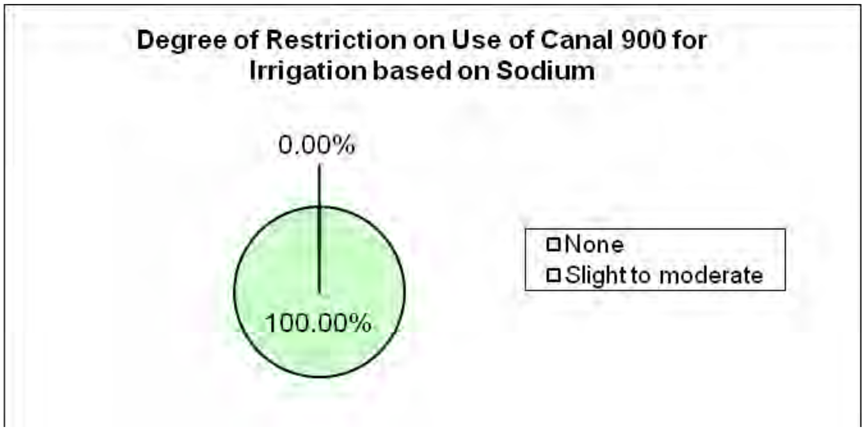


Figure 60: Degree of Restrictive on Canal 900 Water Use for Irrigation Based on Sodium Levels

Additionally, based on restrictive water use associated with levels of bicarbonates in water (<90mg/l none; 90-500 mg/l slight to moderate; >500 mg/l severe), results show that the high bicarbonate levels canal 900 irrigation water fall within the slight to moderate restrictive water category for irrigation (figure 62).

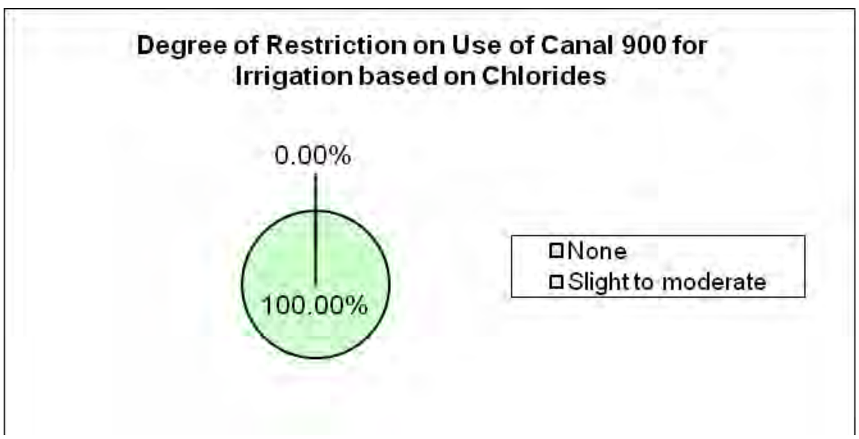


Figure 61: Degree of Restriction on Canal 900 Water Use for Irrigation Based on Chloride Levels

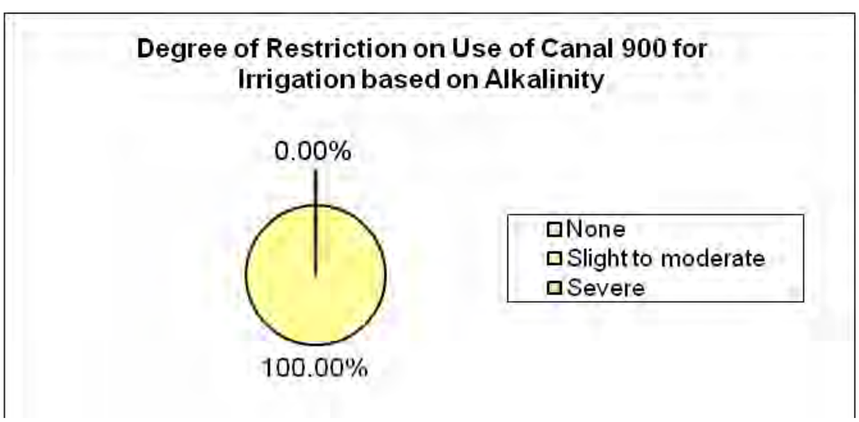


Figure 62: Degree of Restriction on Canal 900 Water Use for Irrigation Based on Bicarbonate Levels

Finally, in reference to the presence of toxic trace metals (table 5), and despite the addition of copper sulfate to control algae growth, results of the study show that the levels of trace metals are mostly below acceptable limits with the exception of cadmium with mean level of 0.01034 /l exceeding the maximum acceptable level of 0.01 mg. still, only 20% of the canal water samples were tested for trace metals. As such, it is important to monitor water quality to verify levels of cadmium in irrigation water.

Additionally, evaluating the microbiological profile of canal 900 irrigation water sources for irrigation use all the sampled sites exceeded the recommended limit of 1000/100ml for the total coliform count but none exceeded the recommended level of 100/100ml for fecal coliforms. Still, as will be discussed later, the residence time of microorganisms in soil and on crops is impacted by climate conditions, types of soil, availability of irrigation water, the type of crops to be grown, proper pest control and proper management strategies.

On the other hand evaluating the water quality for irrigation in reference to the proposed national standards (based on the biochemical oxygen demand levels and fecal coliform counts), results show that sampled sites fall within class 1 A suitable for irrigation.

5.5.2. WATER FOR LIVESTOCK USE

Based on the conductivity levels of all sampled water sites, the quality of spring water sources is suitable for use by livestock (reference to tables 7 and 8). Additionally, results of the study show that the levels of magnesium in water samples do not exceed 85mg/l with a mean level of 19.00 mg/l and a standard deviation of 9.2 mg/l. As such, based on the indicated parameters, the quality of the sampled irrigation water sites along canal 900 is suitable for drinking by all types of Livestock.

Still, when evaluating the presence of trace metals in livestock drinking water results show that the main concern is the level of cadmium that should be monitored to insure that the recommended levels are not exceeded (table 7-9).

5.6. WASTEWATER QUALITY ASSESSMENT

5.6.1. DOMESTIC WASTEWATER (SEWAGE)

Agronomic and economic benefits can result from wastewater use in agriculture. Irrigation with wastewater can increase the available water supply or safeguard better quality supplies for other types of utilization. In addition to the direct economic benefits reflective of natural ecological water conservation, wastewater provides an abundant source of nitrogen and phosphorous; sewage can supply all the nitrogen and much of the phosphorus and potassium required for agricultural crop production, reducing on the application of fertilizers. In addition, micronutrients and organic matter also provide additional benefits. However, the suitability of a raw, untreated wastewater for irrigation is governed by wastewater salinity, infiltration rate plant toxicity in addition to major issues associated with health risks (WHO 2006). As such, special management practices are essential to manage use, maintain good crop yields, and as important, reduce exposure to health risks.

The health and non-related health risks associated with the use of wastewater have been coupled with the issues relating to:

- The scarcity of alternative water supplies,
- The need to enhance crop production, and
- The increased exposure of surface water to sources of pollution and as such, the progressive degradation of these viable water resources.

Moreover, as indicated before the acceptable quality of wastewater for irrigation should be judged on the potential severity of the problems that may result during long-term use. And, resulting problems vary both in kind and degree, and are modified by soil characteristics, climate and type of crop, as well as by proper skilled management.

5.6.1.1. SEWAGE SALINITY

Evaluating water quality based on the risk of increased soil salinity, results show that in reference to the levels of total dissolved solids (TDS) associated with restrictive water use (<450 mg/l none; 450-2000 mg/l slight to moderate, and >2000 umhos/cm severe), 75% wastewater samples fall within the slight to moderate degree of restrictive use (figure 63) in comparison to restriction on 23% of sampled river sites, as presented before (Figure 30).

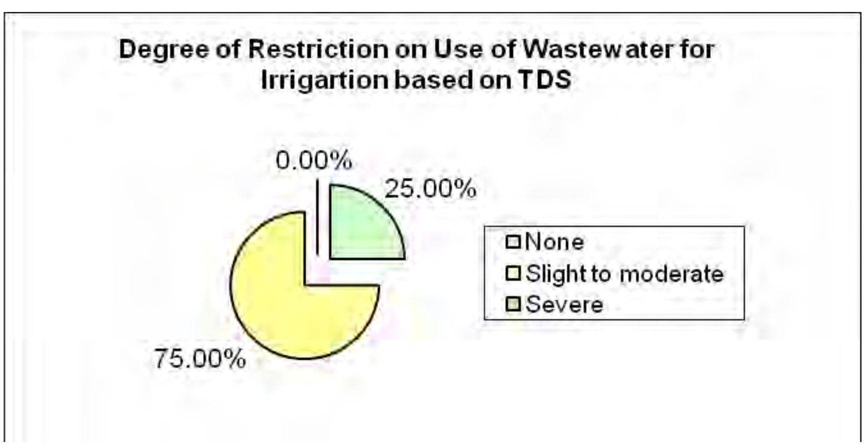


Figure 63: Degree of Restriction on Sewage Use for Irrigation Based on the Electric Conductivity (EC) of Wastewater Samples

5.6.1.2. WASTEWATER INFILTRATION RATE

Infiltration problems, as indicated before, occur when irrigation water remains at the soil surface too long, or infiltrates too slowly to provide the crop with sufficient amounts of water to maintain acceptable yields. The infiltration rate of water into soil depends on the quality of the irrigation water (organic load and the chemical content= sodium relative to the calcium and magnesium) and soil characteristics (e.g. structure, degree of compaction), (WHO 2006)

As such, low salinity water or water with high sodium to calcium ratio will decrease infiltration. These factors can have an additive impact, especially if irrigation periods are prolonged to achieve adequate infiltration. Such added impacts may result in crusting of seedbeds, excessive weeds, nutritional disorders and drowning of the crop, rotting of seeds, lack of aeration, plant and root diseases Additionally, among the serious side effects of infiltration is the potential to develop disease and vector (mosquito) problems (WHO 2006)

Based of these two restrictive factors (EC and SAR Ratio), results of the study show that about 42% of wastewater samples fall within the slight to moderate restriction (Figure 64). When compared to results of surface water (81% of the sampled wastewater fall within the slight to moderate restriction zone on water use for irrigation)

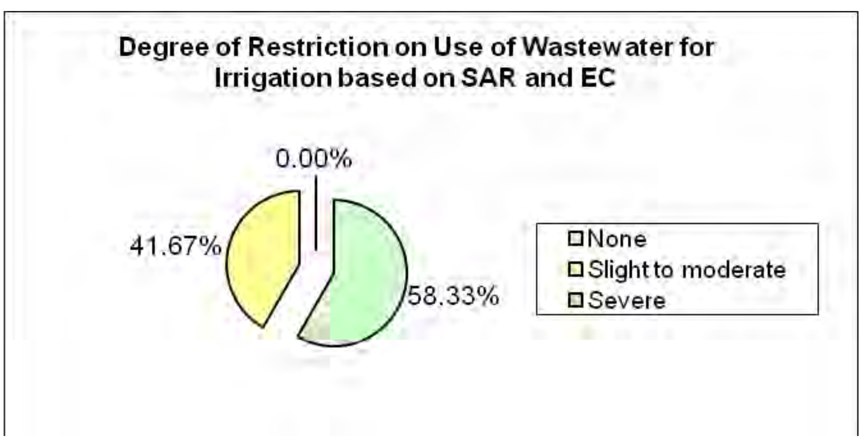


Figure 64: Degree of Restriction on Domestic Wastewater Use for Irrigation Based on Electrical Conductivity and SAR Levels

5.6.1.3. PLANT TOXICITY

As indicated before, toxicity problems occur if certain constituents (ions) in the soil or water are taken up by the plant and accumulate to concentrations high enough to cause crop damage or reduced yields. The degree of damage depends on the uptake and the crop sensitivity. The permanent, perennial-type crops (tree crops) are the more sensitive. Damage often occurs at relatively low ion concentrations for sensitive crops. It is usually first evidenced by marginal leaf burn and interveinal chlorosis. If the accumulation is great enough, reduced yields result. The more tolerant annual crops are not sensitive at low concentrations but almost all crops will be damaged or killed if concentrations are sufficiently high (Ayers and Westcot, 1994; Westcot, 1997)

As such, relating to the levels of sodium in sewage associated with restrictive sewage use (<70 mg/l minimal; >70 mg/l slight to moderate), results show that 33% of the wastewater samples fall within the slight to moderate restriction category (Figure 65) in comparison to less than 4% for sampled surface water (32).

As for chloride and in reference to levels associated with restrictive sewage use for irrigation (<100 mg/l none; >100 mg/l slight to moderate), results show that 75% fall within the slight to moderate restrictive category for irrigation use (Figure 66) in comparison to 20% of sampled surface (Figure 33).

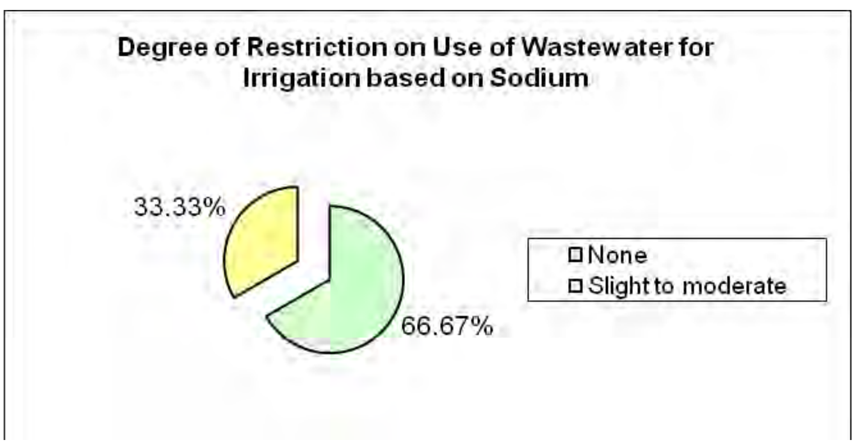


Figure 65: Degree of Restriction on Domestic Wastewater Use for Irrigation Based on Sodium Levels

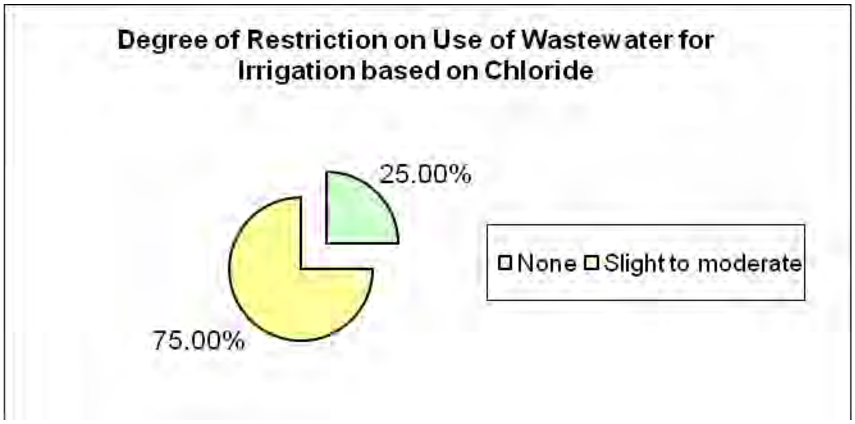


Figure 66: Degree of Restriction on Domestic Wastewater Use for Irrigation Based on Chloride Levels

Additionally, in reference to the levels of boron in water, levels were below detectable levels to be associated with restrictive water use. Moreover, based on restriction on sewage use associated with levels of bicarbonates in water (<90mg/l none; 90-500 mg/l slight to moderate; >500 mg/l severe), results show that the high bicarbonate levels of about 92% of wastewater samples fall within the slight to moderate category of restriction on use, and 8% within the category of severe restriction (Figure 67) in comparison to surface water sampled sites falling within the slight to moderate restriction category (Figure 34).

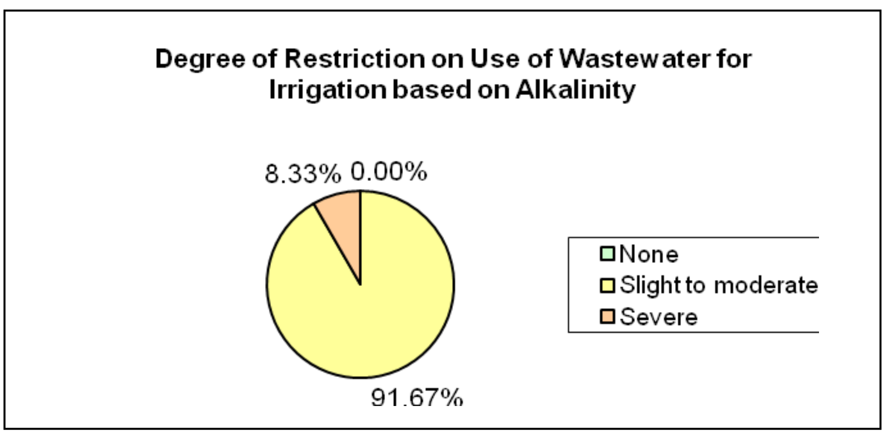


Figure 67: Degree of Restriction on Domestic Wastewater Use for Irrigation Based on Bicarbonate Hardness Levels

However, in reference to the presence of toxic trace metals and the corresponding categories of restrictive water use, results show that the levels are not coupled with restrictive water use for irrigation.

On the other hand evaluating the wastewater quality for irrigation use in reference to the proposed national standards for reclaimed wastewater use in agriculture, results show that the high BOD levels (mean value of 1123 mg/l) and fecal coliform load restrict wastewater use for direct crop irrigation.

5.6.1.4. HEALTH RISKS ASSOCIATED WITH WASTEWATER USE

Wastewater or natural water supplies exposed to wastewater discharge are likely to contain pathogenic organisms similar to those in the original human excreta (WHO 2006):

- Bacteria**;** associated mostly with diarrhea (the most prevalent type of infection), cholera, typhoid, paratyphoid and other *Salmonella* type diseases.
- Viruses; of particular importance the adenoviruses, enteroviruses (including polioviruses), hepatitis A virus, reoviruses and diarrhoea-causing viruses (especially rotavirus).
- Protozoa; of particular importance *Giardia lamblia, Balantidium coli* and *Entamoeba histolytica*.
- Helminths; mostly do not multiply within the human host, however, soil, water or plant life can act as intermediate hosts for the propagation of the disease agent

The survival time of pathogens in fresh water and sewage is presented in table 13. The survival times may however, may be altered by the type or degree of sewage treatment prior to use or discharge into the water body. As most sewage treatment is designed to reduce organic pollution some pathogenic organisms will reach the agricultural fields when the water is used. As such, whether sewage is treated, partially treated, or untreated water, pathogenic organisms will be present and as such, site management to minimize or eliminate the potential risks is essential.

Table 13: Survival Times of Excreted Pathogens in Freshwater and Sewage at 20-30°C

Pathogen	Survival time (days)
Viruses[a]	
Enteroviruses[b]	<120 but usually <50
Bacteria	
Faecal coliform[a]	<60 but usually <30
***Salmonella* spp.**[a]	<60 but usually <30
***Shigella* spp.**[a]	<30 but usually <10
Vibrio cholera[c]	<30 but usually <10
Protozoa	

***Entamoeba histolytica* cysts**	<30 but usually <15
Helminths	
***Ascaris lumbriocoides* eggs**	Many months

Source: FAO,1997

Mostly all excreted pathogens can survive in soil for periods of time exceeding the survival on crops that are directly exposed to sunlight and desiccation. Nevertheless, survival times can be long enough in some cases to pose potential risks to crop handlers and consumers (the survival times of selected excreted pathogens in soil and on crop surfaces are presented in table 14.

Table 14: Survival Times of Selected Excreted Pathogens in Soil and on Crop Surfaces at 20-30°C

Pathogen	**Survival time (days)**
Viruses[a]	
Enteroviruses[b]	<120 but usually <50
Bacteria	
Faecal coliform[a]	<60 but usually <30
***Salmonella* spp.**[a]	<60 but usually <30
***Shigella* spp.**[a]	<30 but usually <10
Vibrio cholera[c]	<30 but usually <10
Protozoa	
***Entamoeba histolytica* cysts**	<30 but usually <15
Helminths	
***Ascaris lumbriocoides* eggs**	Many months

Source FAO, 1997

As such, the determining factors for sewage use include climate conditions, types of soil, availability of irrigation water, the quality of the wastewater to be used, the type of crops to be grown, proper pest control and proper management strategies. Focusing on exposure to public health risks, the level of the risk can be classified in the following manner (ADD Reference):

"Lowest risk to consumer (field worker protection needed):

Crops not for human consumption (for example cotton, sisal).

- Crops normally processed by heat or drying before human consumption (grains, oilseeds, sugar beet).
- Vegetables and fruit grown exclusively for canning or other processing that effectively destroys pathogens.

- Fodder crops and other animal feed crops that are sun-dried and harvested before consumption by animals.
- Landscape irrigation in fenced areas without public access (nurseries, forests, green belts)".

"Increased risk to consumer and handler";

- Pasture, green fodder crops.
- Crops for human consumption that do not come into direct contact with wastewater, on condition that none must be picked off the ground and that spray irrigation must not be used (tree crops, vineyards, etc.).
- Crops for human consumption normally eaten only after cooking (potatoes, eggplant, beetroot).
- Crops for human consumption, the peel of which is not eaten (melons, citrus fruits, bananas, nuts, groundnuts).
- Any crop not identified as high-risk if sprinkler irrigation is used".

"Highest risk to consumer, field worker and handler "

- Any crops eaten uncooked and grown in close contact with wastewater effluent (fresh vegetables such as lettuce or carrots, or spray-irrigated fruit).
- Landscape irrigation with public access (parks, lawns, golf courses").

5.6.2. INDUSTRIAL WASTEWATER QUALITY ASSESSMENT

Industrial wastewater effluents these should not be used for irrigation mostly due to problems associated with soil salinity and crop toxicity mostly due to the high levels of total dissolved solids (mean level of 1248 mg/l), high BOD levels (mean value of 1767 mg/l, bicarbonate alkalinity (mean value of 388 mg/l) and fecal microbial loads). Moreover, relatively high levels of Barium were detected in industrial wastewater samples (mean value of 00916 mg/l) in comparison to a mean level of 0.00317mg/l detected in domestic wastewater. This reflects on the major source of pollution leading to the increase in barium levels in surface water.

As such, the industrial sector is mostly contributing to the increase in the levels of barium in the water and soil sediments (as will be presented), whereas increased levels of cadmium and manganese may be attributed to agricultural (fertilizers and pesticides) and industrial activities along the river and its tributaries.

5.7. SOIL QUALITY ASSESSMENT

Soil is the product of weathering of rocks and mineral deposits and represents the interaction between the atmosphere, the biosphere and hydrosphere. The presence of heavy metals in large amounts in soils can be harmful to plants, animals, and people. Heavy metal content of soils is of major significance in relation to fertility and nutrient status. Metals such as Zn and Cu are essential elements for normal growth of plants and living organism. However, high concentration of these elements becomes toxic. Other metals like Cd, As, Pb, Hg in low concentration, may be tolerated by the ecosystem, but they become harmful at higher concentration. Recently, a great deal of concern has been expressed over soil contamination with heavy metals due to rapid industrialization and urbanization (Skordas & Kelepertsis, 2005; Govil et al, 2008).

Metals can bio-accumulate in plants and animals and eventually reach humans through the food chain (Skordas & Kelepertsis, 2005. Govil et al, 2008). Soil samples represent an excellent media to monitor heavy metal pollution as they usually deposit in topsoil. Furthermore, soils do not only serve as sources of certain metals but also function as sinks for metal contaminants. As indicated before, the Upper Litani Basin is exposed to various sources of point and non point sources of pollution. Nevertheless, heavy industries are relatively minimal, and the main activities relate mostly to food processing plants, a textiles and paper industries. Still, it is of important to determine the content of heavy metals (As, Ba, Cd, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb & Zn) in soils.

The sources of metals and the associated health risks are presented in table 15. The collected soil samples from the Upper Litani Basin are referred to soil samples and the soil samples irrigated with Irrigation Canal 900 are referred to as canal soil samples. The analytical results are presented in appendices. The soil chemical profile was compared to the Canadian Soil Quality Guidelines for the Protection of Environmental and Human Health as presented in table 16 (CCME, 1999).

Results show that Molybdenum (Mo) and Cobalt levels (Co), whether in soil or canal-soil samples, were below detection limits. While barium (Ba) was detected in all samples (soil and canal soil samples) but the levels were below Canadian guidelines for agricultural use (Figure 68).

Table 15: Sources of Metals and Related Health Risks

Metal	Source	Projected Health Risk
As	Pestisides, Wood Preservatives, Glass Products	Liver and Nervous System Damage, Cancer
Ba	Cement, Ceramic Glazes,Glass & Paper making, Pharmaceutical and Cosmetics Products	Little is known about possible health effects. The degree of absorption depends on solubility of compound. High amounts > 2 mg/L- Cardiovascular diseases
Cd	Batteries, Plastics, Fertilizers, Pesticides, Paints, Electroplating	Bone and Cardiovascular Diseases, Cancer, Liver and Nerve Cell Damage
Co	Alloy, Ceramics and Paints	Respiratory Irritation, Heart Damage and Failure, Thyroid Problems
Cr	Stainless Steel, Alloy, Cast Iron, Pigments and Wood Treatment, Tanneries	Cr (III) has bioavailability and toxicity than Cr (VI). However, high doses of both cause gastrointestinal irritation, Stomach ulcer, kidney and liver damage, Cr (IV) is Carcinogenic
Cu	Smelting and Metal plating operations, Fertilizers and Animal Feeds, Electrical Works, Pesticides and Fungicides	Gastrointestinal diseases, Anemia, Liver and Kidney Damage
Hg	Electrical Industry, Paints, Pesticides and Fungicides	Adrenal Disfunction, Brain and Central Nervous System Damage, Haring Loss. Research suggests that it may contribute to autism and multiple sclerosis.

Mn	Steel and Alloys; $MnSO_4$ is used as Fertilizer, Ceramics, and Fungicide, MnO_2 Dry-cell Batteries, Fireworks, $KMnO_4$ as Disinfectants	Little is provided for its toxicity or health and it is related to water hardness
Mo	Steel and Alloys, Fertilizers, Ceramics and Plastics	Molybdenum and its Compounds are Highly Toxic leading to Liver Dysfunction, Joint Pains Articular Deformities, Erythema, and Edema of the Joint Areas
Ni	Alloys, Electroplating, Ceramics, Pigments, Alkaline Batteries, Catalyst in Plastic and Rubber Industry	Gastrointestinal Distress and Intestinal Cancer, Kidney and Heart Damage, Dysfunction
Pb	Smelting Operation, Automobile Emission, Urban Runoffs, Pesticides, Plastics, Paints, Ceramic Glaze	Central Nervous System and Kidney Damage. Fecal Development, Delay Growth and Learning Disabilities
Zn	Galvanization Works, Motor Oil, Tire Wear, Pigments, Pesticides	Little is known about long term effects of ingesting Zn from food or water. It might cause Anaemia and Pancreas Damage

(Source: Perfect Life Institute, 2002)

Table 16: Canadian Trace Metal Guideline Levels for Soils

Parameter	**Levels in Soil (mg/kg)**
Arsenic (As)	12
Barium (Ba)	750
Cadmium (Cd)	1.4
Chromium (Cr)	64
Cobalt (Co)	40
Copper (Cu)	63
Lead (Pb)	70
Manganese (Mn)	470
Molybdenum	5

Mercury (Hg)	6.6
Nickel (Ni)	50
Zinc (Zn)	200

(Source: Adapted from Alloway, 2005)

As for lead only 4% (one sample) exceeded the Canadian guideline by more than 2.3 folds (Figures 69-70). The source of this metal is most probably due to small-scale industrial activities in Al-Marj village. However, all soil canal samples were far below the Canadian guideline recommended values and 86 % of samples were below detection limits.

Also, only 8% of soil samples had Zn and Cu levels higher than the Canadian guideline levels (Zn: 200 mg/kg; Cu: 63 mg/kg). But, all soil canal samples had zinc at lower levels than the Canadian guideline; whereas 25 % of canal soil samples had copper at higher levels (Figures 71 and 72). This is mostly contributed to the addition of copper sulphate to control algae growth in the irrigation canal.

Furthermore, Zn and Cu exhibited strong significant correlation ($r=0.8$, $p < 0.01$). The sources of these metals are primarily geological and to lesser extent anthropogenic (solid waste dumps in Ferzol and Al Marj).

Contrary to this finding, Ni and Cr levels in all canal soil samples (Figure 73 and 74) were higher than the Canadian guideline for agricultural use (Ni: 50 mg/kg; Cr: 64 mg/kg). Whereas, 96 % of soil samples showed higher values for Ni; 92 % samples showed higher levels for chromium. Nickel and Chromium are mostly associated with multi-industrial activities, (a stainless steel, alloys, ceramics, plastic, rubber, tannery industries as presented table 16. Such small-scale industrial activities run all through Upper Litani Basin (ULB). However, tanneries could not be identified in villages with high Cr levels (Kamed Al Louz and Qarraoun; Cr: 350 mg/kg, 6 times higher than recommended values).

Furthermore, the impact of agricultural runoff was explicit for the presence of arsenic, mercury and cadmium. For As; 84% of soil samples (Figure 75) showed levels above the Canadian guideline for agricultural use (As: 12 mg/kg). The range of arsenic was between 6 mg/kg to 28 mg/kg. Similar range values (9-26 mg/kg) were detected for canal soil samples (Figure 75); with 92% of canal soil samples exhibiting higher levels than the guideline level. As is mainly contributed by agricultural runoff water (As is a constituent in pesticides). Soils collected east and west of canal, mainly in Jeb Janin and Kamed el Louze, have high arsenic levels (≅23 mg/kg). These areas are mainly agricultural.

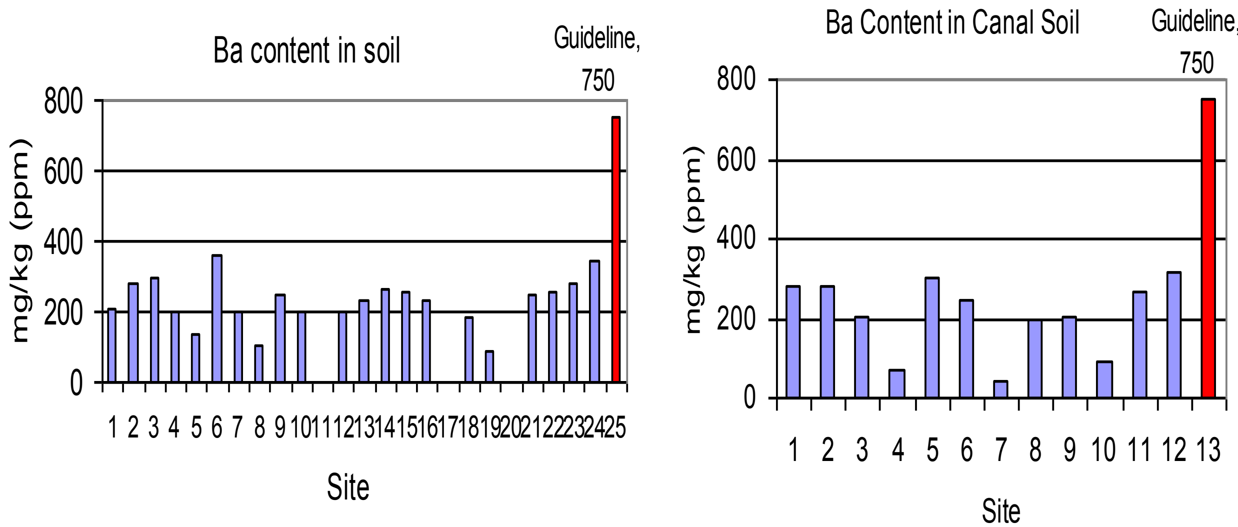


Figure 68: Barium Levels in Soil Samples (mg/kg)

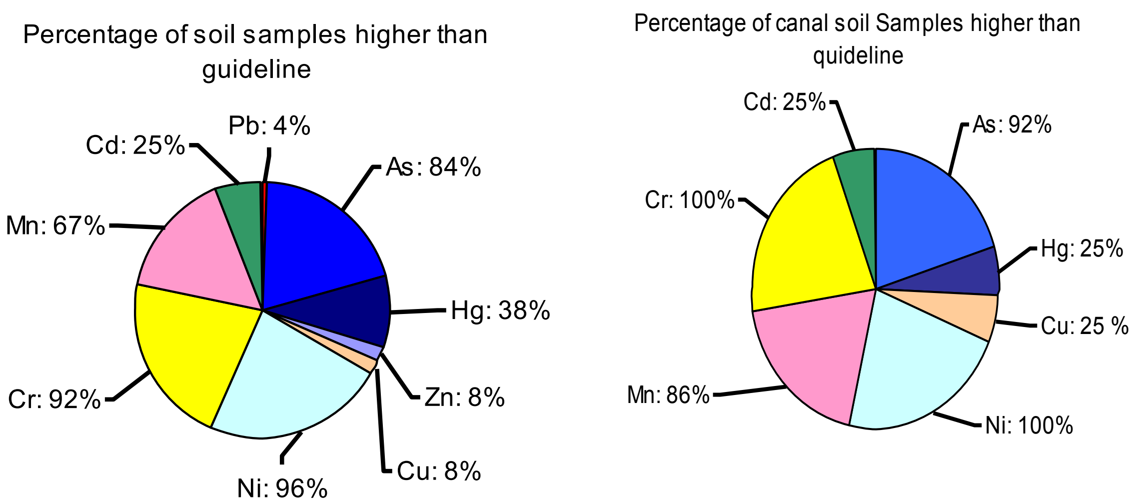


Figure 69: Percentages of Analyzed Soil Samples Higher than the Canadian Guideline Levels for Agricultural Use

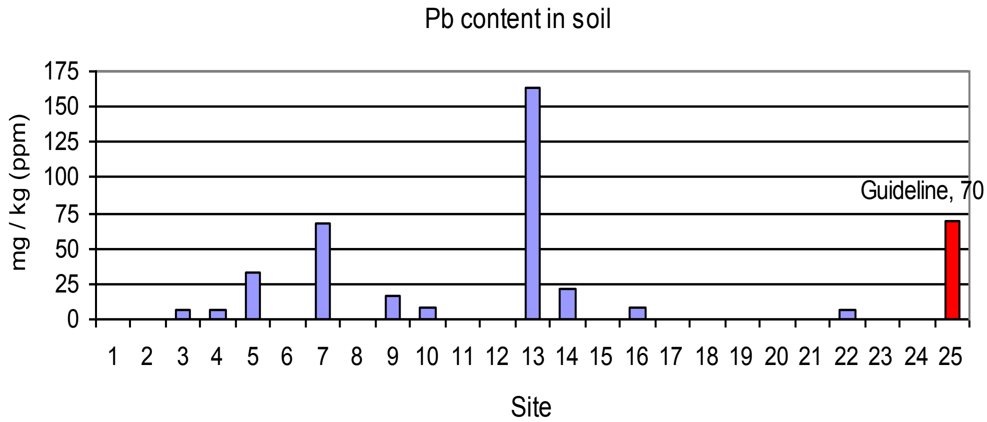


Figure 70: Lead Levels in Soil Samples (mg/kg)

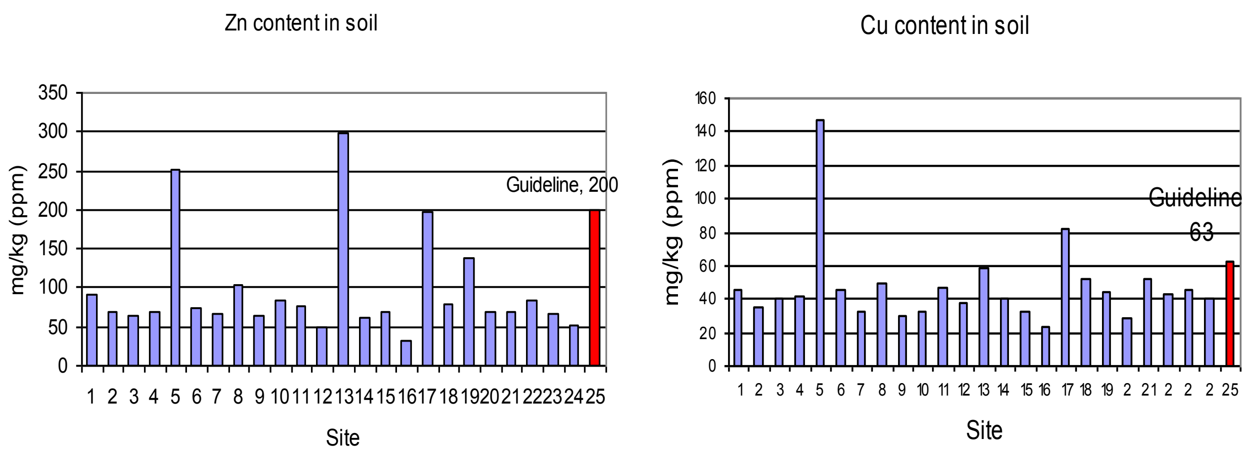


Figure 71: Copper and Zinc in Soil Samples (mg/kg)

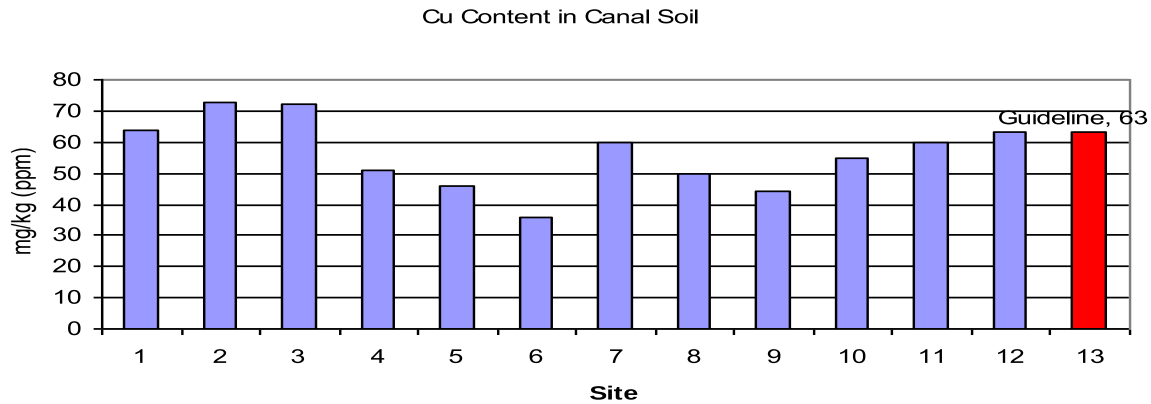


Figure 72: Copper Levels in Irrigation Canal 900 Soil Samples (mg/kg)

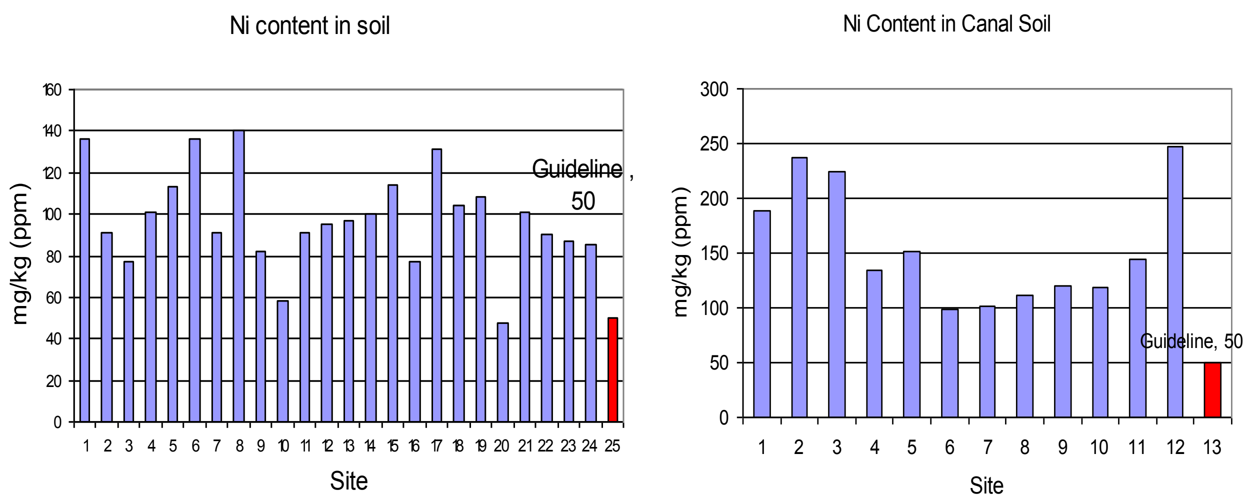


Figure 73: Nickel Levels in Soil and irrigation Canal Soil Samples (mg/kg)

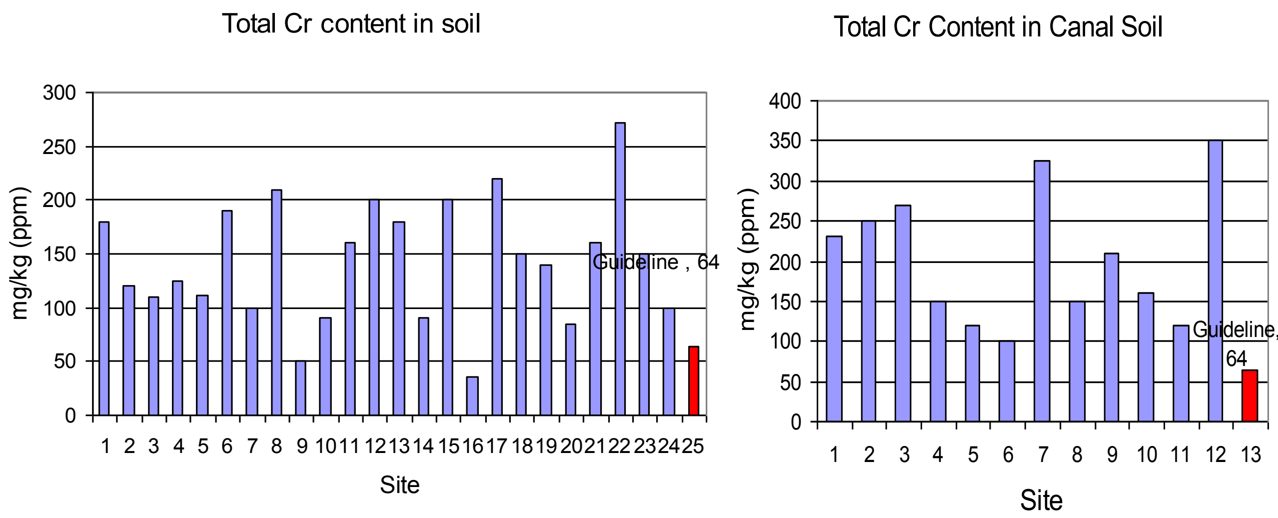


Figure 74: Chromium Levels in Soil and Canal Soil Samples (mg/kg)

Additionally, mercury levels in soil and canal soil samples were higher by 1.2 folds in comparison to the Canadian guideline of 6.6 mg/kg. The highest level was detected in Ferzol (9 mg/kg) mainly due to agricultural activities and solid waste dump sites (Figure 76).

As for cadmium, 25 % of soil and canal soil samples levels were higher than the Canadian guideline level of 1.4 mg/kg). Cadmium is a constituent of pesticides and fertilizers, thus high levels of Cd are to be expected agricultural sites (Figure 77).

Lastly, manganese levels in 67% of soil samples and 86% of canal soil samples (Figure 78) were higher than the Canadian guideline level of 500 mg/kg. This may be attributed to the geological formation, especially since Mn exists in coincidence with Fe; or may have resulted due to existing agricultural and industrial activities (steel and alloy, fertilizers, fungicides and fireworks). Moreover, the presence of cadmium and manganese in soil and canal soil sediments is concurrent with the detection of these elements in water samples (surface water, springs, lake and irrigation canal).

Comparing to the BAMAS study reported results, the presence of cadmium, copper and cadmium was only detected. As such, the levels of trace metals are building up in soil due to irrigation with industrial and domestic wastewater (as industrial wastewater is directly discharged into the river or sanitary sewers discharging into the river and its tributaries) and surface and ground water exposed to such sources of pollution. Moreover, although the mobility of trace metals and the uptake by plants is mostly limited by the soil alkalinity, still, crop toxicity may result. As such, it is important to determine the levels of these elements in crops for proper risk assessment.

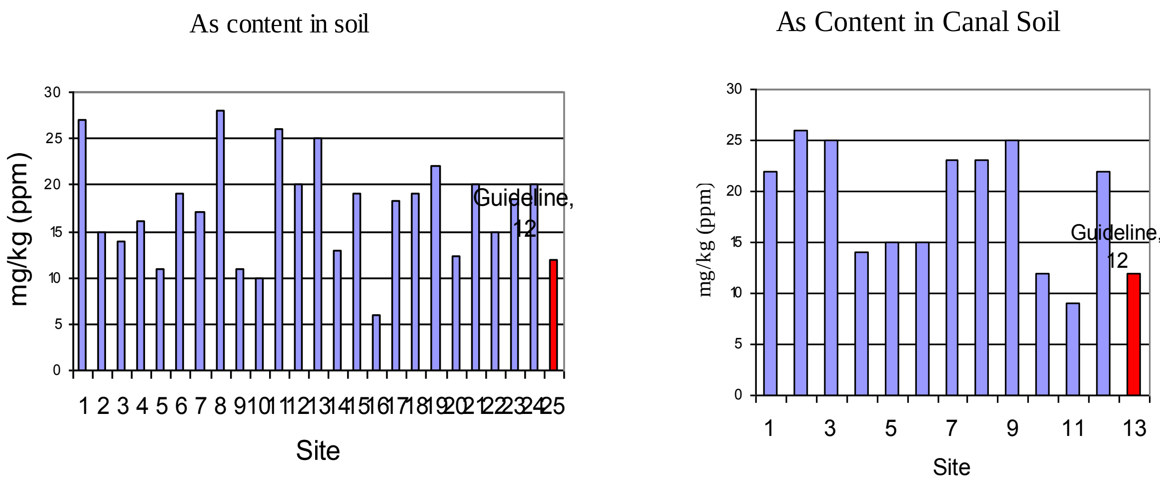


Figure 75: Arsenic Levels in Soil Samples (mg/kg)

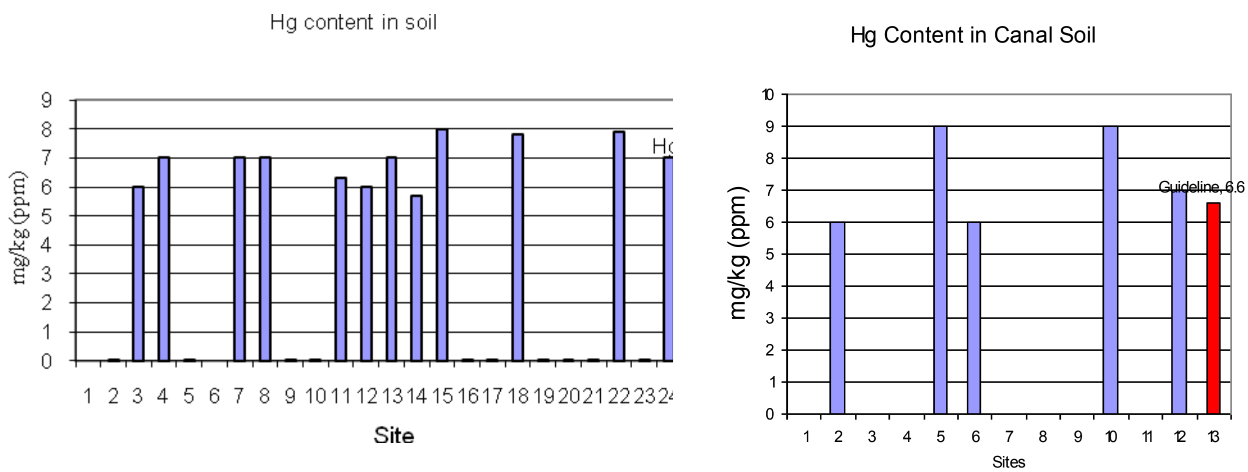


Figure 76: Mercury Analytical Profile in Soil (mg/kg)

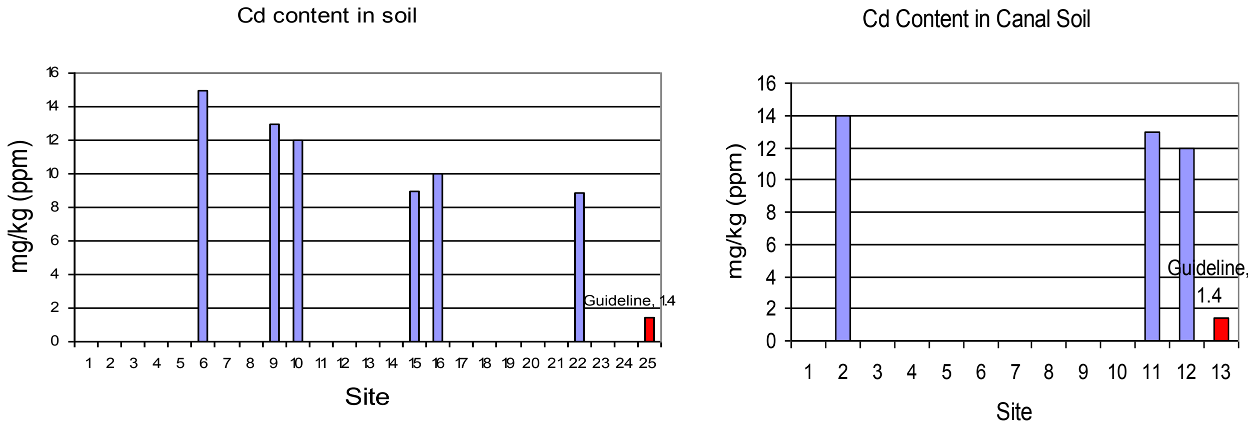


Figure 77: Cadmium Analytical Profile in Soil samples (mg/kg)

5.8. SEDIMENTS QUALITY ASSESSMENT

Sediments are sinks for heavy metals entering rivers from anthropogenic sources, such as industrial and municipal wastewater effluents, land-fill leacheat, and agriculture runoff. Many trace metals of toxicological significance (e.g. As, Cd, Hg, Pb) have low solubility's in the at pH levels of natural waters, and river sediments are the sink holes of such trace metals (Korfali & Davies, 2005, Korfali et al., 2006). Similar to

soil, sediments are considered as excellent media for monitoring contaminating levels of heavy metal.

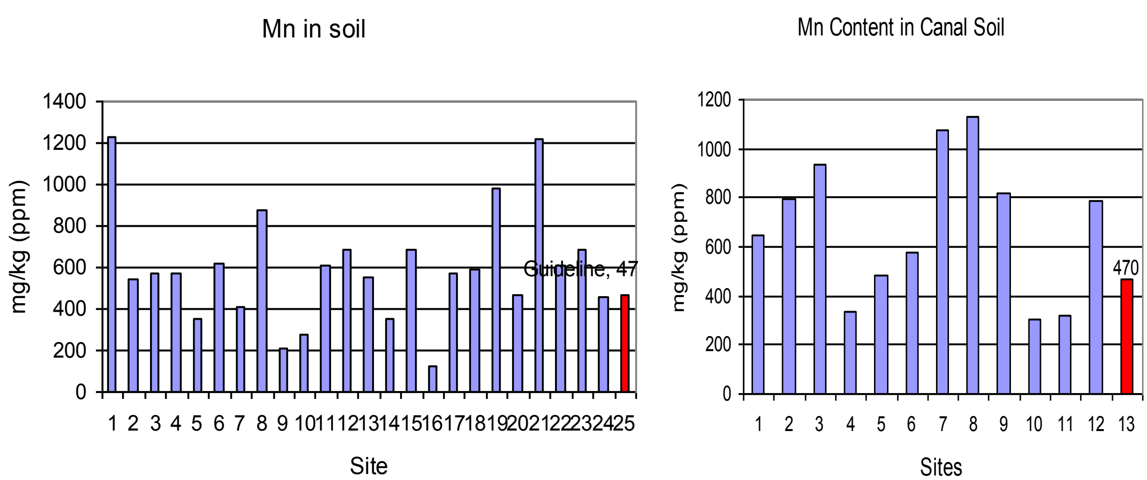


Figure 78: Manganese Levels in Soil Samples (mg/kg)

The haphazard dumping and disposal of industrial and domestic wastes into the Litani River and tributaries has been previously discussed. While it is well known that most potential pollutants in aquatic sediments are nontoxic/nonavailable forms, there are situations where sufficient concentrations of potential pollutants are present to harm aquatic organisms and consequently released to the overlying water column. Furthermore, aquatic sediments can accumulate in aquatic species and become a threat to human health as a result of their consuming these aquatic organisms as food. Thus, as in soils, it is of importance to determine the content of heavy metals in the alluvial sediments. Sediment samples collected (if accessible) from Upper Litani River Bed are referred to as (SE), and sediments collected from the Qaraoun Lake are denoted as (SEQ).

The chemical analytical profile was compared to the Sediment Quality Criteria and Guidelines for the protection of freshwater aquatic systems. The Canadian guidelines (CCME, 1999): ISQG (Interium Sediemnt Quality Guideline) and PEL (Probable Effect Level) presented in table 17 were used to evaluate sediment quality. These guidelines are used in risk assessment studies by toxicologists and epidemiologists to reflect on the level of the potential risks. However, certain metals (Ba, Mn & Ni) were compared to the Texas Sediment Quality Guidelines (TNRCC, 1996), as they are not referred to by the Canadian Guidelines.

Table 17: Sediment Quality Criteria and Guidelines

Parameter	Fresh Water Sediments		
	ISQG[1] (mg/kg)	**PEL[2] (mg/kg)**	**SOG[3] (mg/kg)**
Arsenic (As)	5.9	17	-
Barium (Ba)	-	-	189
Cadmium (Cd)	0.6	3.5	-
Chromium (Cr)	37.3	90	-
Copper (Cu)	35.7	197	-
Lead (Pb)	35	91.3	-
Manganese (Mn)	-	-	490
Mercury (Hg)	0.17	0.486	-
Nickel (Ni)	-	-	-
Zinc (Zn)	123	315	-

[1]Canadian Interim Sediment Quality Guideline [2]Canadian Probable Effect Level

[3]Texas Sediment Quality Guideline

Accordingly, molybdenum (Mo) and cobalt (Co) levels were not detected in all sediment samples whereas manganese (Mn) was detected at levels (figure 79) below the Texas sediment quality guideline values (SQG: 490 mg/kg). Similarly, levels of lead (Pb) levels of most sediment samples were below ISQG (35 mg/kg) and PEL (91.3 mg/kg) as presented in figure 80.

Moreover, copper (Cu) and zinc (Zn) levels were below the PEL guideline except for one sample that exhibited levels higher than the ISQG guideline (Figures 81-82). The detected level of Copper is 114 mg/kg and that of Zinc is 456 mg/kg. Both metals are found in concentrations 3.2 folds the ISQG level. This site is exposed to industrial wastewater discharge from the nearby potato chip industry. However, neither Cu nor Zn is a constituent of this discharge. The source of these metals could be river dump sites (corrosion of cans and metal objects)

Moreover, cadmium (Cd) and barium (Ba) like Cu and Zn were only detected in one sediment sample (each at a different location). Most of sediment samples were under the detection limit for Cd except, as mentioned previously for one sample near Jeb Janine where the level of Cd (11 mg/kg) exceeded the ISQG guideline (0.6 mg/kg) by nearly by 20 folds and the PEL guideline (3.5 mg/kg) by 3.5 folds (Figure 83), However, as Jeb Janine village is mainly characterized by an agricultural profile, then most probably the source of Cd is the agricultural runoff (pesticides and fertilizers).

Similarly, the barium level is higher than the guideline value at Jeb Janine sampling site (2 folds the SQG guideline level of 189 mg/kg) as presented in Figure 84. The source of Barium in the sediment at this site could not be identified.

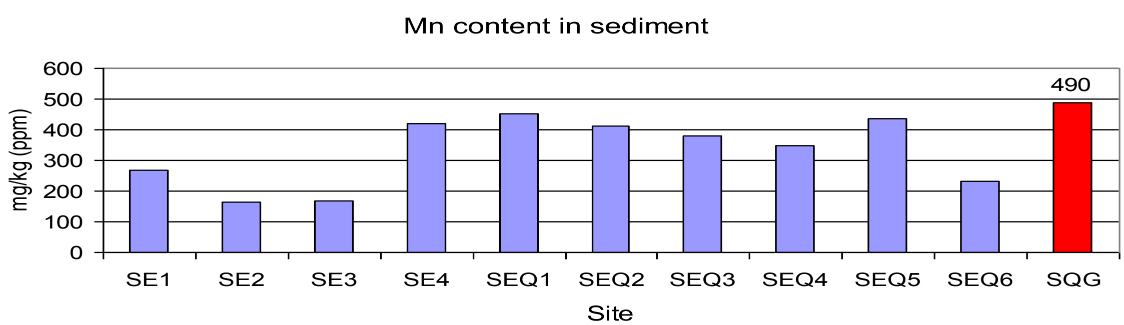


Figure 79: Manganese Levels in Sediment Samples (mg/kg)

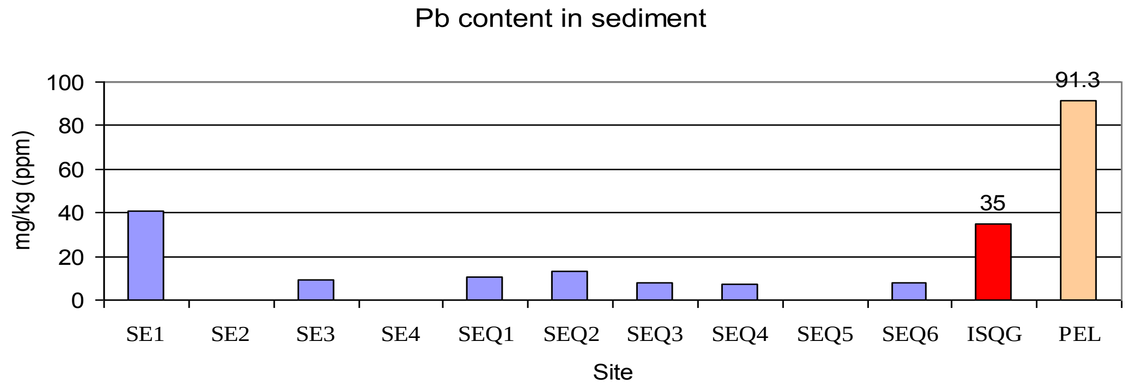


Figure 80: Lead Levels in Sediment Samples (mg/kg)

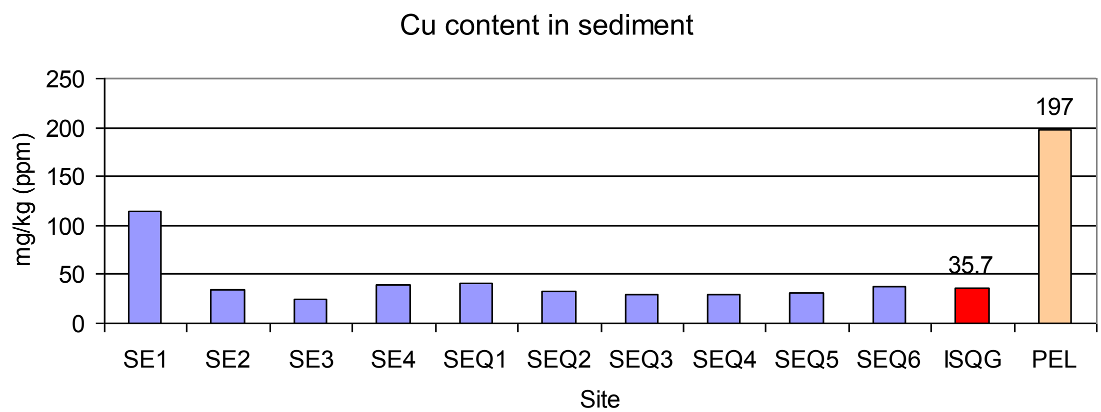


Figure 81: Copper Levels in Sediment Samples (mg/kg)

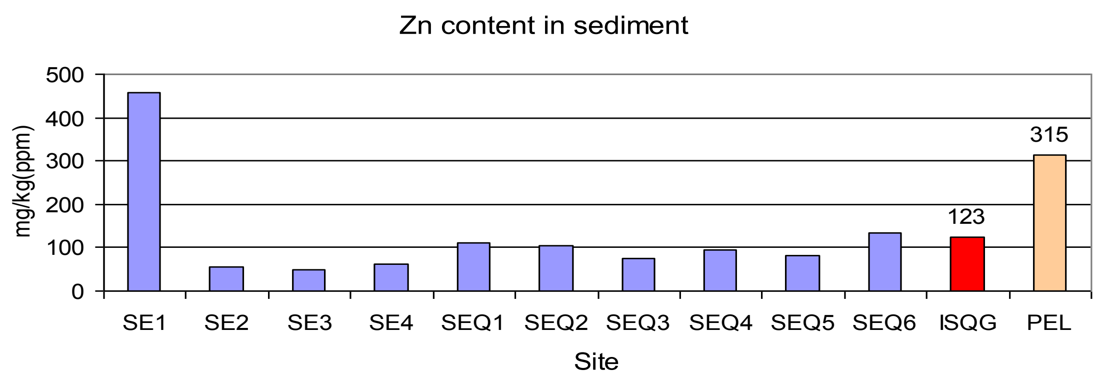


Figure 82: Zinc Levels in Sediment Samples (mg/kg)

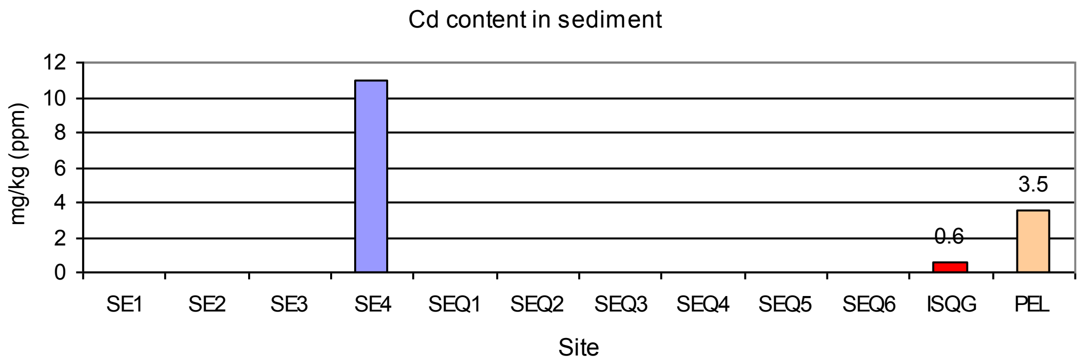


Figure 83: Cadmium Levels in Sediment Samples (mg/kg)

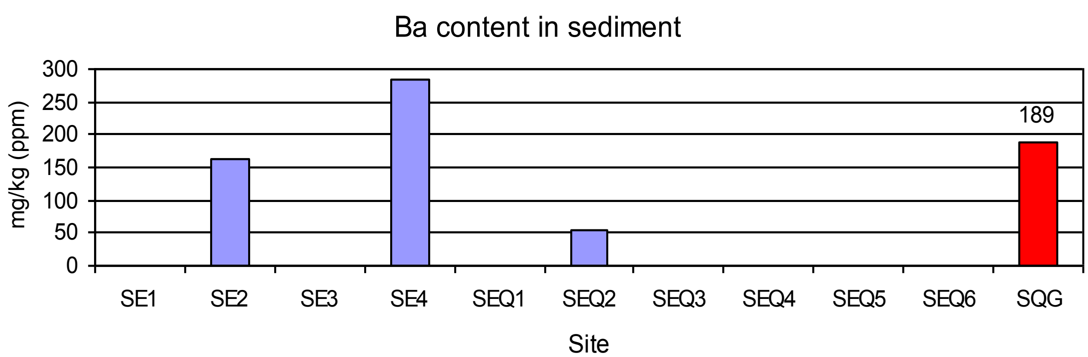


Figure 84: Barium Levels in Sediment Samples (mg/kg)

Conversely, levels of Nickel (Ni) were above the SQG (25.2 mg/kg), ranging between 36 mg/kg to 128 mg/kg as presented in figure 85. The highest level was detected in the sediment sample from the last accessible sampling point along the Qaraoun Lake (by the dam).

Furthermore, the detected levels of Arsenic (As) in all sediment samples were above the ISQG (5.9 mg/kg) and below the PEL (17 mg/kg); ranging between 7 and 16 mg/kg (Figure 86).

As for Nickel, detected levels in sediments and soil samples were above guidelines levels. Hence, and based on the presented profile (figure 85), the most probable source is the type of geological formations. Contrary to this assumption, the high detected levels of Arsenic cannot be related only to the geological formation, since As exhibits lower levels in different types of drainage basins. Nevertheless, the higher amounts of arsenic in sediments coincided nearly with sites that exhibited high levels of As in corresponding soil samples (e.g. Jeb Janine). The most probable source is agricultural activities, due to the excessive application of pesticides.

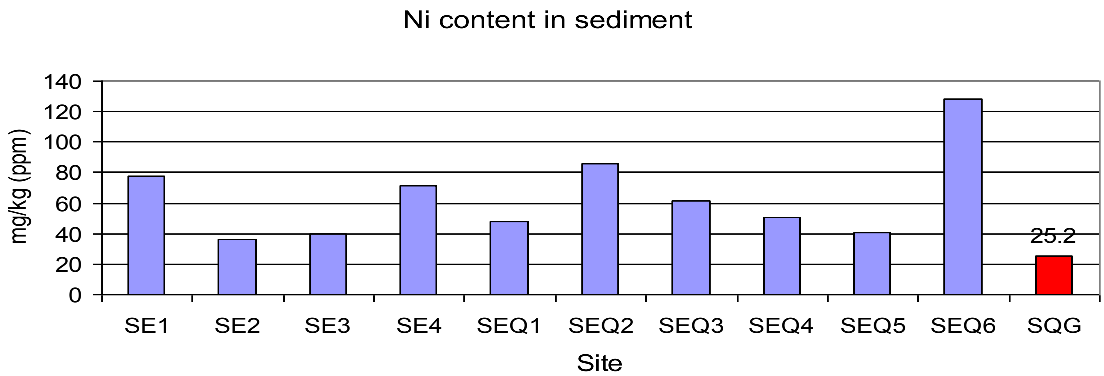


Figure 85: Nickel Levels in Sediment Samples (mg/kg)

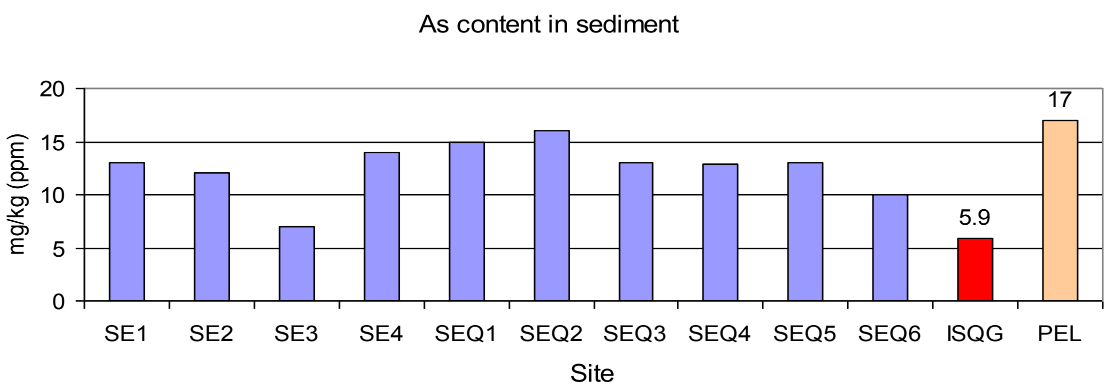


Figure 86: Arsenic Levels in Sediment samples (mg/kg**)**

As for the levels of mercury, 40% of the samples had levels exceeding the Canadian guidelines as presented in Figure 87. The high levels were mainly detected in the Qaraoun Lake sediments. Mercury is contributed by electric works, paints, application of pesticides and fungicides. Since electroplating and paints industries were not observed in the vicinity of Qaraoun Lake, then the most probable source would be the agricultural runoff.

Furthermore, chromium (Cr) was also detected at levels exceeding the ISQG guidelines of 37.3 mg/kg, in 40% of the sediment samples (levels ranging between 50- 110 mg/kg) as presented in figure 88. The highest detected level was in the sediment samples along the river bed in Ferzol and Jeb Janine; both of which are characterised by agricultural activities. As other sources of Cr (tanneries, alloy and steel works) could not be identified, consequently, the main source of Cr in sediments could be attributed to agricultural runoff.

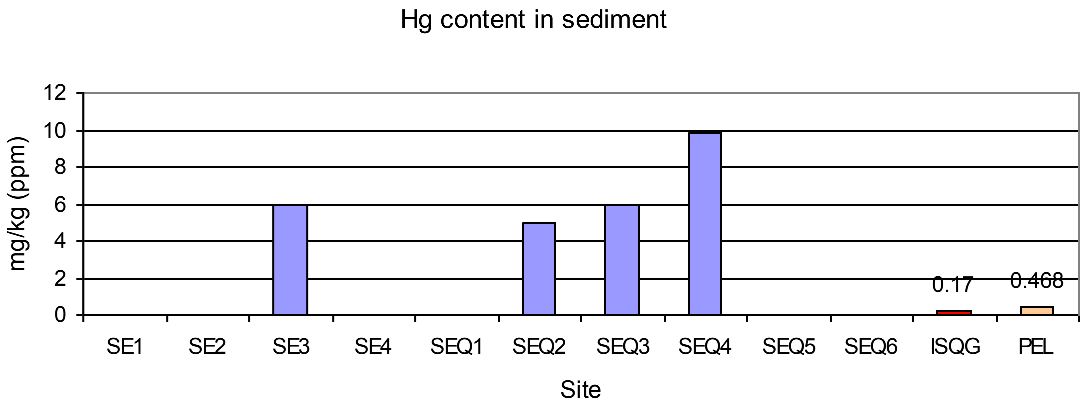


Figure 87: Mercury Levels in Sediment Samples (mg/kg)

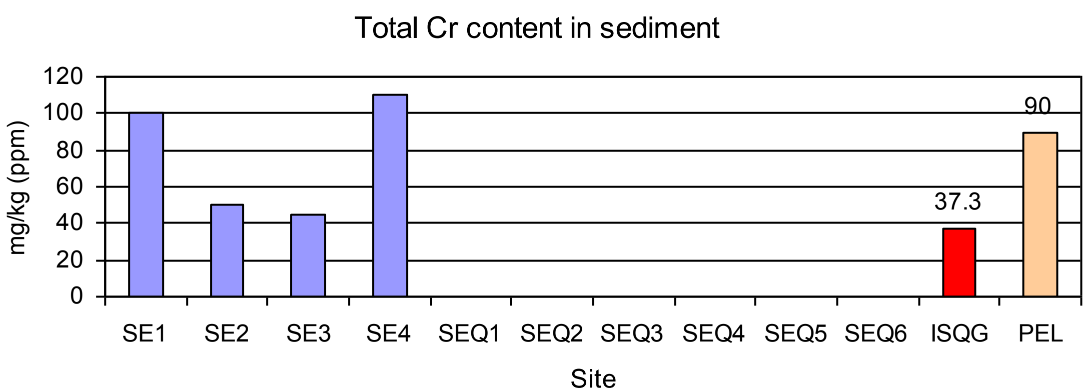


Figure 88: Chromium Levels in Sediment Samples (mg/kg)

6. CONCLUSION AND RECOMMENDATIONS

6.1. CONCLUSION

6.1.1. UPPER LITANI RIVER BASIN CHARACTERISTICS

Screening the major cities and villages (a total of 60) cities and villages of the Upper Litani Basin reflects on (a) the deficient quality and type of environmental services provided for the management of municipal solid waste and domestic wastewater(sewage), (b) the lack of compliance in implementing onsite measures to insure the proper management of the various sources and types of industrial wastes (solid and liquid), (c) the excessive dependence on groundwater and raw untreated sewage as a source of irrigation water, (d) the excessive application of pesticides, fertilizers and animal manure, (e) the flourishing "query business" and the prevalence of stone cutting open sites, and the direct location of recreational activities along the river bank and its tributaries; and clearly defines the following point and nonpoint sources of pollution:

- Domestic Wastewater (sewage); cesspools discharges and sanitary sewer system outlets,
- Municipal solid waste dump sites,
- Agricultural runoff,
- Food processing plants (e.g. sugar beet, dairy products, fruit jam, and juices, vegetable canning) wastewater effluents,
- Industrial zones (dyeing and tanning, electroplating, manufacturing of batteries, chemicals, sponge and paper) wastewater effluents,
- Farm (swine, cows, sheep and poultry) waste, and
- Recreational areas (hotels and restaurants) sewage discharge and solid wastes dump sites.

The detailed description of the profiles of cities and villages within the ULB is presented in appendices.

6.1.2. LITANI RIVER WATER QUALITY PROFILE ASSESSMENT

Among the 50 sampling sites (along the Litani river and its tributaries), identified by the reconnaissance survey, 24 sites (48%) were found dry (Figure 5). Additionally, minimal water flow was observed along the river and its tributaries, as the water springs and the resulting river tributaries are mostly "completely" tapped for irrigation or are dry (Jeb El Habash, Faour and Jdeita water springs).

The river flow within the upper zone of ULB is relatively minimal, mostly non-existing and is mainly sustained by domestic (sewage) and industrial wastewater effluents. Hence, the river is mostly stagnating, has a foul smell, a dark black color, and supports the excessive growth of Bamboo and Lavender. In the mid ULB Zone the river flow is also minimal and is heavily exposed to sewage and industrial wastewater discharge. The water is blue green in color due to the extensive growth of algae, and the presence of tadpoles, water snakes, fish and turtles is evident. Reaching the lower zone of the ULB, the river starts with minimal water flow that supports extensive algae growth and the presence of fish, water snakes, and turtles, ducks etc. It then flows into the Quaroun Lake with relatively more water input due to the feeding of major water springs in this area.

The levels of oxygen are less than 5mg/l (needed to support aquatic life) in about 46% of sampled sites despite the excessive growth of algae along the lower (Green), and middle (Orange) zones of the ULB. In comparison, the dissolved oxygen reported by the BAMAS 2005 study was 5.93 mg/l. This drop in oxygen levels along the river and its tributaries is concurrent with the increased biological oxygen demand of 11 folds (from 48 mg/l in 2005 to 548 mg/l in 2010). Additionally, about 62% of the sampled sites have BOD > 30 mg/l (recommended level for river viability).

Accordingly, the major identified hot spots are in Hezzine, Ferzol, Ablah, Jdeita, Al Marj, Taanayel, Ammiq, Dier Zanoun, and Jeb Janine reflecting on exposure to organic sources of pollution (e.g. domestic wastewater (sewage), municipal solid waste dump sites, food processing plants wastewater discharge (poultry and dairy plants), specific types of industrial wastewater effluents (e.g. paper mills) and agricultural runoff.

Identifying possible water extraction sites, to meet the increased water demands of growing communities, is difficult as such sites are highly limited due to the minimal water flow, high organic loads, the presence of detected trace metals (mostly cadmium and manganese and to a lesser extent barium) and fecal contamination. Mostly this is associated with direct sewage discharge, scattered solid waste dump sites leachates, industrial wastewater effluents and excessive applications of fertilizers and pesticides.

Moreover, assessing the water quality for possible domestic water use the following can be concluded (tables 3 and 4):

- The increase in the mean TDS from 290 mg/l (BAMAS Study 2005) to 503 mg/l (1.7 folds) reflective of increased exposure to contamination loads (despite efforts to increase sewerage coverage, sewer outlets still discharge along the river and its tributaries), Additionally, 23% of sampled sites exceed the recommended national standard level of 500 mg/l,

- The increase in pH levels towards alkalinity; from 7.09 (BAMAS Study 2005) to 7.93 (a major reflection of exposure to sewage, leachate of solid waste dump sites, and food processing plants' effluents etc.),

- The High mean levels of ammonia exceeding in all sampled sites the recommended national standard level (in comparison the BAMAS 2005 Study reported 87% noncompliance). This is expected under conditions of reduced oxygen content which is not sufficient to oxidize the high ammonia content,

- The minimal levels of nitrates not exceeding the recommended standard levels. Still, this is also reflective of reducing conditions, and as such is not reflective of acceptable water quality,

- The moderate levels of phosphates (12.01 mg/l as PO4) reflective of exposure to sewage point sources of pollution. Comparing to the recommended national standard level about 69% of sampled sites exceed the acceptable limits. This finding is comparable to the 68% non-conformity reported by the BAMAS 2005 Study.

- The minimal levels of sulfates (mean level of 23.5 mg/l) also reflective of reducing conditions not on acceptable water quality. Concurrently, under conditions of minimal oxygen, high levels of H2S are associated with the foul smell, as is the case,

- Cadmium levels exceeding the Lebanese standard level of 0.005 mg/l by 1.98 folds. Additionally, levels in 45% of the sampled sites exceed the Lebanese standard and in 54% of the sampled sites exceed the WHO guideline level of 0.003mg/l. In comparison levels were not detected in the previous study (BAMAS 2005),

- Manganese levels exceeding the national and EPA standard level of 0.05 mg/l by 1.4 folds in 42% of the sampled sites. In comparison, levels were not detected in the previous study, and

- The levels of Barium are building up, with a mean level of 0.273 mg/l in comparison to the national standard of 0.500 mg/l,

- Fecal contamination in 50% of the sampled sites and the presence of streptococcus feacalis in one sampling site (3% of sample). In comparison, fecal coliforms were reported in 92% of the tested samples in 2005 (BAMAs 2005). This is not reflective of better quality and is mainly due to minimal levels of oxygen that do not support the residence time in water and the destruction of the fecal organisms in the shallow water film by sunlight (near UVB radiation).

As for the suitability of the water for irrigation use, based on international guidelines and standards, relatively minor restrictions are associated with (a) increased soil salinity relating to increased TDS, (b) reduction in water infiltration rate due to increased sodium and manganese level, (c) projected crop toxicity (main element of concern, among tested metals, is cadmium as the mean level of 0.0099 mg/l is approaching the maximum recommended level of 0.01 mg/l), (e) deposits on leaves and fruits associated with increased bicarbonate levels and (e) microbiological safety based on the total and fecal coliform counts (Figures 30-34 and Tables 5 and 6).

On the other hand evaluating the water quality for irrigation in reference to the proposed national standards (based on the biochemical oxygen demand levels and fecal coliform counts), results show that sampled sites fall within the maximum limits of class 3 based on the high BOD levels. This is mainly due to the discharge of organic contaminants from the various indicated sources of pollution, as discussed before. On the other hand, when comparing to the levels of fecal organisms, mostly 15% of the sampled sites fall within class 2 to the max of class 3. As such, direct irrigation from the river is not recommended.

Lastly, evaluating the quality of the surface water for livestock use, the main limiting factor for such type of use is neither the high TDS, nor the magnesium levels, but the levels of trace metals (Tables 8-9).

As such, direct discharge of point and nonpoint source of pollution limits the suitability of the water quality for irrigation. Moreover, tapping springs and river tributaries "completely" for irrigation is destroying the ability of the river and its tributaries to handle the increasingly high loads of contaminants disposed. This is subsequently limiting the ability of the river to restore oxygen levels and to enhance the self purification capacity needed to regenerate water quality for acceptable multipurpose usage.

6.1.3. GROUND WATER SOURCES

6.1.3.1. SPRINGS OF THE ULB

A total of 24 major water springs were identified through the field survey of the Upper Litani Basin; 4 springs (15%) of which are dry in summer. The location and GPS coordinates of the sampled water springs are presented in figures 7-8. Mostly the ground water sources are located in combined domestic,

agricultural and to a lesser extent industrial and recreational settings. However, these sources are mostly tapped for use as irrigation water in summer.
Evaluating the physical, chemical and microbiological water quality profile of spring water sources for domestic usage, the following can be concluded:

- An overall mean mineral content of 284 mg/l. This level of TDS is acceptable when compared to the Lebanese standards, EPA standards and the WHO guidelines recommended levels,
- Mostly all macro-elements and microelements fall within the sets limit values recommended by the Lebanese standards, EPA standards and WHO guidelines,
- The cadmium mean level of 0.00736 mg/l, exceeds the recommended national standards of 0.005 mg/l b by 1.5 folds,
- The magnesium mean level of 0.07 mg/l, exceeds the recommended guideline level of 0.05 mg/l) by 1.4 folds,
- The Barium levels are building up, but still below the acceptable levels,
- Fecal coliforms were detected in 67% of sampled springs, and Streptococcus faecalis in 33% of sampled springs.

As such, the quality of spring water sources should be continuously monitored as the impacts of pollution sources are becoming evident. It is crucial to screen all springs used by communities as complementary domestic water sources in order to determine water safety based on the set Lebanese standard for drinking water. Additionally, sources used to feed domestic networks should also be continuously monitored. Determination of the levels of trace metals should be an integral component of this quality assessment. Sources exceeding acceptable levels for trace metals should not be used and alternative sources should be immediately identified.
As for the suitability of the water for irrigation use, based on international guidelines and standards, relatively this is governed by minor restrictions associated with (a) reduction in water infiltration rate due to increased sodium adsorption rate, (b) deposits on leaves and fruits associated with increased bicarbonate levels (mainly due to the geological formation and sewage discharge), and (c) microbiological safety (61% exceeded the recommended limit of 1000/100ml for the total coliform count and 15% exceeded the recommended level of 100/100ml for fecal coliforms).
As for suitability of water for livestock use, the main hendering factor is neither the high TDS, nor the magnesium levels and is mainly due to high levels of cadmium and manganese.

6.1.3.2. WELL WATER QUALITY ASSESSMENT

A total of 25 accessible wells were identified through the field survey of the Upper litany Basin. The location and GPS coordinates of the sampled wells are presented in figures 7-9. Mostly these ground water sources are located in combined domestic and agricultural settings and are mostly tapped for domestic water use and for irrigation.

Evaluating the physical, chemical and microbiological quality profile for domestic use, the following can be concluded (Table 10):

- The mean TDS of 385 mg/l is acceptable when compared to the Lebanese standards (still 12% exceed the standard 500mg/l level),
- All tested macro-elements and microelements fall within the sets limit values as recommended by the national Standards, EPA standards and WHO guidelines,
- High nitrate levels >10 mg/l as nitrate N were detected in 20% of the sampled wells in the areas Housh Barada, Hezzine, Sariene, Helanieyeh and Ablah,
- Relatively higher chloride (up to 130 mg/l) and sulfate levels (up to 64mg/l) were also detected in sampled sites showing high nitrate levels (this is mostly associated with the improper management of sewage, and
- Total coliform organisms were detected in 32% of the samples (in comparison to 78% reported by BAMAS Study 2005), fecal coliforms in 16% of samples (in comparison to 35% reported by BAMAS Study 2005) and Streptococcus feacalis in 8% of the samples.

These findings reflect on the efforts to increase the coverage of the sanitary sewer systems. This has definitely reduced on the exposure of ground water aquifers to progressive contamination. Yet, at present, the system is still deficient and sanitary sewer networks have not yet been completed. Additionally, leachate from scattered municipal dumps sites adds to the contamination loads.

As such, the dependence on well water sources for domestic use should be properly evaluated as high nitrate levels are mostly associated with the occurrence of methemoglobinemia (Cyanosis or blue – baby syndrome) in infants and young children. Methemoglobinemia develops when immature infant gut converts nitrates to nitrites which react with haemoglobin to form methemoglobin, so blocking oxygen transport (Afzal, 2006; Rizk, 2009; WHO, 2008). Such sources should not be used and alternative resources should be immediately identified.

As for the suitability of the water for irrigation (based on international guidelines and standards) relatively minor restrictions apply. These restriction are associated with (a) increased soil salinity due to increased TDS levels, (b) reduction in water infiltration rate due to increased sodium and manganese levels (c) deposits on leaves and fruits associated with increased bicarbonate levels (mostly due to nature of geological formations and sewage discharge) and (e) microbiological safety as 16% of samples exceeded the recommended limit of 1000/100ml for the total coliform count and 8% exceeded the recommended level of 100/100ml for fecal coliforms.

As for suitability of water for livestock use, well water can be used with no restrictions relating to the levels of total dissolved solids, magnesium and trace metals.

6.1.4. QARAOUN LAKE WATER ASSESSMENT

The water quality profile of the Qaraoun Lake has changed over the past 5-10 years. Comparing the lake water quality profile reported by the BAMAS 2005 study and the findings of the 2010 study, as presented in table 12, the main findings reflect on:

- Increase in the overall total dissolved oxygen, masking the increase in biological oxygen demand (boasted by organic contaminants),
- Increase in the levels of dissolved oxygen reflective on suspended algae growth,
- Change in pH towards alkalinity reflective mostly of exposure to domestic wastewater discharge and industrial wastewater discharge, as specified before,
- levels of cadmium exceeding the recommended Lebanese standard level of 0.005 mg/l by 2 folds and the higher levels are reported in the mid lake water zone (trace metals were below detectable levels in BAMAS 2005), and
- Increase in fecal loads (50% of sampled sites are contaminated with fecal organisms)

This change in the quality of the water profile is concurrent with the progressive exposure to contamination loads from the various point and nonpoint sources identified in the Upper Litani Basin.

Additionally, comparing the existing physicochemical water profile with that reported by Jurdi et.al (2001) shows that the mid zone (2.5- 3.6 km from receiving zone) that was considered as the "better water extraction zone" for multi-purpose usage (lower organic loads, and higher scavenging of metals in the sediments) is at present a relatively reducing medium (higher organic loads and more solubility of metal sediments). This variability in the water quality makes it difficult to define a better "quality" water zone for possible water extraction for multipurpose use.

The most probable explanation to this major finding relates to the disposal of sewage directly by the lake. A wastewater treatment plant located directly by the lake is under construction in Bab Merea (treat domestic wastewater from Saghbine). Meanwhile, sanitary sewer system (coverage has increased, replacing the point sources cesspools) outlets discharge directly into the lake, awaiting the completion of the treatment plant.

Moreover, comparing the existing physicochemical water profile with that reported by Jurdi et.al (2001) shows that the mid zone (2.5- 3.6 km from receiving zone) that was considered as the "better water extraction zone" for multi-purpose usage (lower organic loads, and higher scavenging of metals in the sediments) is at present a relatively reducing medium (higher organic loads and more solubility of metal sediments). This variability in the water quality makes it difficult to define a better "quality" water zone for possible water extraction.

The most probable explanation to this major finding relates to the disposal of sewage directly by the lake. A wastewater treatment plant located directly by the lake is under construction in Bab Merea (treat domestic wastewater from Saghbine). Meanwhile sanitary sewer systems coverage has increased, replacing the point sources cesspools. Yet, the sanitary sewer is currently being discharged into the lake, awaiting the completion of the treatment plant. Additionally, another plant Wastewater Treatment plant, located directly by the lake is under construction in Saghbine. Meanwhile, collected sewage is discharged directly into the lake. As such, the delay in "closing the loop"; completing the wastewater treatment plants, and ensuring proper treatment, is boasting the level of organic contaminants in the lake.

6.1.5. IRRIGATION CANAL 900 WATER QUALITY ASSESSMENT

Changes in the water quality are evident when compared to the results of the BAMAS 2005 study (table 12) and reflect the mainly on:

- Increase in the levels of total dissolved solids (from 191 to 340; 1.78 folds) reflective of progressive exposure of the Qaraoun Lake to point and nonpoint sources of pollution as presented before,
- Minimal change in the levels of dissolved oxygen despite the progressive growth of algae. This is mostly due to the increase in the biochemical oxygen demand from <2 to 9 mg/l (4.5 folds),
- Change in pH towards alkalinity (from 7.09 to 7.90) reflective of exposure to domestic wastewater discharge, industrial wastewater discharge, etc. as specified before, and
- Decrease in fecal loads

This change in the quality of the water profile is concurrent with the progressive exposure to contamination loads from the various point and nonpoint sources identified in the Upper Litani Basin.
As for the suitability of the water for irrigation use, based on international guidelines and standards, the relatively minor restrictions relate to (a) reduction in water infiltration rate due to increased sodium and manganese level, and (b) deposits on leaves and fruits associated with increased bicarbonate levels associated with progressive exposure to the various sources of pollution and (c) crop toxicity associated with the cadmium levels approaching maximum recommended levels.
On the other hand evaluating the water quality for irrigation in reference to the proposed national standards for wastewater reuse (based on the biochemical oxygen demand levels and fecal coliform counts), results show that sampled sites fall within class 1 A suitable for irrigation.
Lastly, evaluating the quality of the irrigation canal 900 for livestock, results show that this source can be used without any restrictions on water quality.

6.1.6. WASTEWATER QUALITY ASSESSMENT

As for the suitability of the domestic wastewater (sewage) for irrigation use (based on international guidelines and standards) the relatively major restrictions relate to (a) increased soil salinity due to increased TDS levels, (b) reduction in water infiltration rate due to increased sodium and manganese levels (c) crop toxicity due to increased levels of chlorides and sodium (d) deposits on leaves and fruits associated with increased bicarbonate levels (mostly due to nature of geological formations and sewage discharge) and (e) microbiological safety.
On the other hand evaluating the water quality for irrigation in reference to the proposed national standards for wastewater reuse (based on the biochemical oxygen demand levels and fecal coliform counts), results show that wastewater should not be used for direct crop irrigation.
Additionally, industrial wastewater effluents should not be used for irrigation mostly due to the high levels of total dissolved solids (mean level of 1248 mg/l), BOD levels (mean value of 1767 mg/l, bicarbonate alkalinity (mean value of 388 mg/l) and microbial loads (in samples with lower BOD levels and relatively more oxygen to support the residence of fecal organisms). Moreover, relatively higher levels of Barium were detected in industrial wastewater samples (mean value of 00916 mg/l) in comparison to the mean level detected in sewage (0.00317mg/l) samples. As such, the industrial sector is mostly contributing to the increase in the levels of barium in the water and soil sediments, whereas, increased levels of cadmium and manganese may be attributed to agricultural (fertilizers and pesticides) and industrial activities along the river and its tributaries.

6.1.7. SOIL QUALITY ASSESSMENT

The levels of trace metals are building up in soil due to irrigation with sewage, industrial wastewater and surface and ground water exposed to such sources of pollution. As indicated before barium levels are building up in the different types of water and samples. Concurrently, barium (Ba) was detected in all samples (soil and canal soil samples) but the levels were below the Canadian guidelines for agricultural use (Figure 68).

Ni and Cr levels were detected in all canal soil samples (Figure 73 and 74) at levels higher than the Canadian guideline for agricultural use (Ni: 50 mg/kg; Cr: 64 mg/kg). Whereas, 96 % of soil samples showed higher values for Ni; 92 % samples showed higher levels for chromium. Nickel and Chromium are mostly associated with multi-industrial activities, (a stainless steel, alloys, ceramics, plastic, rubber, tannery industries) as presented table 16. Such small-scale industrial activities run all through Upper Litani Basin (ULB). However, tanneries could not be identified in villages with high Cr levels (Kamed Al Louz and Qarraoun; Cr: 350 mg/kg, 6 times higher than recommended values).

Furthermore, the agricultural runoff effect was explicit for As, Hg, and Cd. For As, 84% of soil samples were above Canadian guideline for agricultural use (As: 12 mg/kg). The range of arsenic was between 6 mg/kg to 28 mg/kg. Similar range values (9-26 mg/kg) were detected for canal soil samples (Figure 75); with 92% of canal soil samples exhibiting higher levels than the guideline levels. Arsenic is mainly contributed by agricultural runoff (As is a constituent in pesticides). Hence, high levels of arsenic (≅23 mg/kg) were detected in soils collected east and west of canal, mainly in Jeb Janine and Kamed el Louze agricultural fields.

Additionally, mercury levels in soil and canal soil samples were higher by 1.2 folds in comparison to the Canadian guideline of 6.6 mg/kg. The highest level was detected in Ferzol (9 mg/kg) mainly due to agricultural activities and solid waste dump sites (Figure 76).

As for cadmium, the levels in 25 % of soil and canal soil samples were higher than the Canadian guideline level of 1.4 mg/kg). Cadmium is a constituent of pesticides and fertilizers, thus high levels of Cd are to be expected at agricultural sites (Figure 77).

Finally, manganese levels in 67% of soil samples and 86% of canal soil samples (Figure79) were higher than the Canadian guideline level of 500 mg/kg. This may be attributed to the geological formation, especially since Mn exists in coincidence with Fe; or may have resulted from existing agricultural and industrial activities (steel and alloy, fertilizers, fungicides and fireworks). Change as levels are high in water. Moreover, the presence of cadmium and manganese in soil and canal soil sediments is concurrent with the detection of these elements in water samples (surface water, springs, lake and irrigation canal).

Comparing to the BAMAS study reported results, the presence of cadmium, copper and cadmium was only detected. As such the levels of trace metals are building up in soil due to irrigation with sewage, industrial wastewater and surface and ground water exposed to such sources of pollution.
Moreover, although the mobility of trace metals and the uptake by plants is mostly limited by the soil alkalinity, still, crop toxicity may result. As such, it is important to determine the levels of these elements in crops for proper risk assessment.

6.1.8. RIVER AND LAKE SEDIMENTS QUALITY ASSESSMENT

While it is well known that most potential pollutants in aquatic sediments are nontoxic/non-available forms, there are situations where sufficient concentrations of potential pollutants are present to harm aquatic organisms and are consequently released to the overlying water column. Furthermore, aquatic sediments can accumulate in aquatic species and become a threat to human health by consuming these aquatic organisms.
Mostly Arsenic levels were detected in all sediment samples above the ISQG (5.9 mg/kg) and below the PEL (17 mg/kg); ranging between 7 and 16 mg/kg (Figure 86).
Nickel was also detected in sediments and soil samples (above guidelines levels). Hence, and based on the presented profile (figure 85), the most probable source is the type of geological formations. Contrary to this assumption, the high detected levels of As cannot be related only to the geological formation, since As exhibits lower levels in different types of drainage basins. Nevertheless, the higher amounts of arsenic in sediments coincided nearly with sites that exhibited high levels of As in corresponding soil samples (e.g. Jeb Janine). The most probable source is agricultural activities, due to the excessive application of pesticides.
Additionally, mercury in 40% of the samples exceeding the Canadian guidelines levels as presented in Figure 87. The high levels were mainly detected in the Qaraoun Lake sediments. Mercury is contributed by electric works, paints, application of pesticides and fungicides. Since electroplating and paints industries were not observed in the vicinity of Qaraoun Lake, then the most probable source would be the agricultural runoff.
Furthermore, chromium (Cr) was also detected at levels exceeding the ISQG guidelines of 37.3 mg/kg, in 40% of the sediment samples (levels ranging between 50-110 mg/kg) as presented in figure 88. The highest detected level was in the sediment samples along the river bed in Ferzol and Jeb Janine; both of which are characterised by agricultural activities. As other sources of Cr (tanneries, alloy and steel works)

could not be identified, consequently, the main source of Cr in sediments could be attributed to agricultural runoff.

6.2. RECOMMENDATIONS

6.2.1. RESTORE LITANI RIVER HEALTH AND WELLBEING

Restoring the Litani River and its tributaries ecologic viability cannot be achieved by a single type of environmental intervention and should be part of the integrated river basin management. As such, a comprehensive approach addressing all types of environmental stresses should be implemented. Furthermore, this objective cannot be achieved without mobilizing the role of communities and empowering municipalities to implement the required environmental interventions.

Moreover, all short and intermediate types of interventions should be part of a comprehensive process to develop, implement and sustain integrated river basin management (IRBM). Instating and sustaining IRBM will ensure the coordination, conservation, management and development of water, land and related resources across all sectors of the Upper Litani Basin. This is essential to maximize the economic and social benefits that can result by restoring and sustaining this freshwater ecosystem. As such, the following short and intermediate measures should be implemented to insure continuous water flow; and to restore the oxygen levels needed to enhance the self purification capacity essential to regenerate the water quality for acceptable multipurpose usage:

- Stop tapping "ALL" the water discharge of springs feeding river tributaries, and the water flow of tributaries, in summer, for irrigation. This is essential to sustain a critical water flow that can cope with the increased pollution loads. Water flow will increase the exposure to aeration and subsequently will regenerate the levels of dissolved oxygen (sustain water flow in comparison to the wet season),

- Control the drilling of new wells and the overexploitation of ground water aquifers. This is crucial to sustain the discharge of water springs and shallow wells. Farmers complain of over pumping of ground water by large irrigation projects, making unavailable to meet agricultural needs. As a start, regulating pumping rates is a must,

- Enforce onsite treatment of major industrial wastewater effluents discharging directly into the Litani River and its tributaries, or into the sanitary sewer of the city/village that outflows directly into the river flow. Just simple physical/primary treatment will reduce the total suspended solids (that increases water turbidity and impacts aquatic life) the biochemical oxygen demand between

35-50%. Additional chemical conditioning may be needed to reducing odors, improve solid and grease removal, neutralize acids and basis and reduce BOD levels,

- Control the discharge of untreated sewage directly into the river and its tributaries. Sanitary sewer systems should replace leaching cesspools. Concurrently, the wastewater treatment plants under construction should be completed within a defined time line (plans have been made since more than 5 years). Currently, this is one of the major limitations to the proper management of sewage,
- Develop and implement a comprehensive plan for the management of sewage. Additionally, treatment plants should be designed to integrate the need not only to reduce BOD but to reclaim and reuse this important resource. As such, treatment process should insure that the quality of treated effluent is suitable for irrigation and livestock. This will help secure sufficient quantities of irrigation water and will preserve the better quality surface and ground water for other types of water usage,
- Control and limit the discharge of municipal solid wastes and industrial solid wastes along the river water flow. Open dump leachates are polluting the river, springs and wells with trace metals that accumulate, temporary, in soil and sediments,
- Properly treat and dispose the sanitary landfill leachate (Zahle landfill) managed to control the leaching of organic and inorganic pollutants and
- Control the application of pesticide. As a start regulating permissible types and application dose of pesticides and fungicides is crucial as toxic trace metals (AS, Cd, Cu, Hg, Pb and Zn) are reaching water bodies (surface and ground) and accumulating, temporary, in soils and sediment as a result of such practices. Farmers' extension programs should be mobilized to achieve this objective.

6.2.2. PROTECT AND SUSTAIN THE QUALITY OF GROUND WATER RESOURCES

The above recommended environmental interventions will also regulate the overexploitation of these resources and reduce the exposure of springs and wells to the various pollution sources. Additionally, the following is also recommended:

- Enforce the existing regulations to replace leaching cesspools with water-tight, properly designed, septic tank. This is critical for villages and areas where the development of sanitary sewer systems is not planned for the near future,
- Regulate the use of fertilizers (types and quantities applied). Excessive use of fertilizers will lead to the dissemination of fecal material, and the enrichment of springs and wells with high levels and nitrates and toxic trace metals such as Cd, Cu, Mn and Mo. These trace metals are detected in surface and spring water sources and to lesser extent in well water sources. Long term exposure will renders the water unsafe for humans and livestock. Moreover treatment to remove these metals is technical and expensive,
- Determine analytically by testing soil samples the need for fertilizer application. Provision of technical laboratory facilities will help the farmer make a better informed decision and apply only the needed amounts of nutrients,
- Identify and screen all water springs used by communities, as complementary domestic water sources, to determine water safety based on the Lebanese standards for drinking water. Additionally, sources used to feed domestic networks should also be continuously monitored. Determining the levels of trace metals should be an integral component of the quality assessment. Sources exceeding acceptable levels for trace metals should not be used, and alternative sources should be immediately identified. This is mostly because such sources will require advanced treatment, beyond disinfection, to insure water safety, and
- Identify, evaluate and monitor well water sources that supply domestic needs. Mostly, the presence of high levels of nitrates associated with the occurrence of methemoglobinemia (Cyanosis or blue – baby syndrome) in infants and young children should be determined. Sources exceeding the recommended standard level should not be used alone (diluted with better quality water) and/or alternative sources should be immediately identified.

6.2.3. REGULATE THE USE OF WASTEWATER FOR IRRIGATION

The suitability of a raw, untreated wastewater for irrigation is governed by wastewater salinity, infiltration rate, plant toxicity in addition to major issues associated with health risks. As such, if needed due to the scarcity of alternative water supplies:

- Regulate use and restrict to the category of lowest risk to consumer (field worker protection needed), as presented in the project document, and
- Determine wastewater quality to insure suitability and to prevent the building up of soil salinity, reduced infiltration and crop toxicity.

6.2.4. ENHANCE THE WATER QUALITY OF THE QARAOUN LAKE

Implementing the above indicated environmental interventions will consequently upgrade the water quality of the Qaraoun Lake for multipurpose uses, especially irrigation and fisheries. Moreover it is recommended to manage properly, the treatment plants constructed along the lake to control the levels of enriching nutrients (mainly phosphates and nitrates) in the discharged effluent. This is critical as excessive algae growth will lead to the development of subsurface reducing water zones that could result in the dissolution of the accumulated trace metals from lake sediments.

6.2.5. ENHANCE THE QUALITY OF IRRIGATION CANAL 900

Implementing the recommended environmental interventions will also upgrade the quality of the irrigation Canal water as it originates from the lake and its quality will fluctuate accordingly. Additionally the levels of added copper sulfate (for controlling algae growth) should be properly controlled and monitored to prevent the progressive accumulation of copper in soils irrigated with the canal water.

6.2.6. DEVELOP AN SUSTAIN WATER QUALITY MONITORING PROGRAMS

It is high time to:

- Upgrade and sustain properly designed comprehensive monitoring activities. This is an urgent need to evaluate water, soil and sediments quality fluctuation and to evaluate the effectiveness of planned environmental interventions,

- Initiate ecological studies to identify biological indicators, monitor the state of aquatic species, an evaluate the need to promote fisheries,

- Conduct follow up surveillance to evaluate existing condition of the Upper Litani Basin at the peak of the wet season. This is essential for comprehensive assessment, and action priority setting,

- Conduct studies to evaluate the level of the risk associated with the translocation of trace metals into the aerial edible portions of crops grown in soil progressively exposed to wastewater irrigation, and surface and spring water contaminated by sewage and industrial wastewater, and

- Conduct studies to evaluate the level of the risk associated with excrete pathogens in fresh water, sewage and their residence time on crop surfaces (eg. Enteroviruses; helminth: Ascaris lambriocoides eggs; protozoa: Entamoeba histolytica).

6.2.7. COMPLETE THE RISK ANALYSIS PROCESS TO:

- Finalize the risk assessment studies, as indicated before. This is essential to base interventions on solid scientific evidence,
- Develop a risk management plan with clearly defined time line, and
- Communicate the current status of the Upper Litani Basin and the proposed management strategy should be shared with communities, municipalities and other relevant stakeholders for feedback. This is essential to mobilize communities and insure collaboration, commitment and compliance.

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8. APPENDIX 1: DETAILED RESULTS

Detailed results are presented per type of sampling:

1 – Surface Results

2 – Spring Results

3 – Well Results

4 – lake Results

5 – Canal 900 Results

6 – Wastewater Results

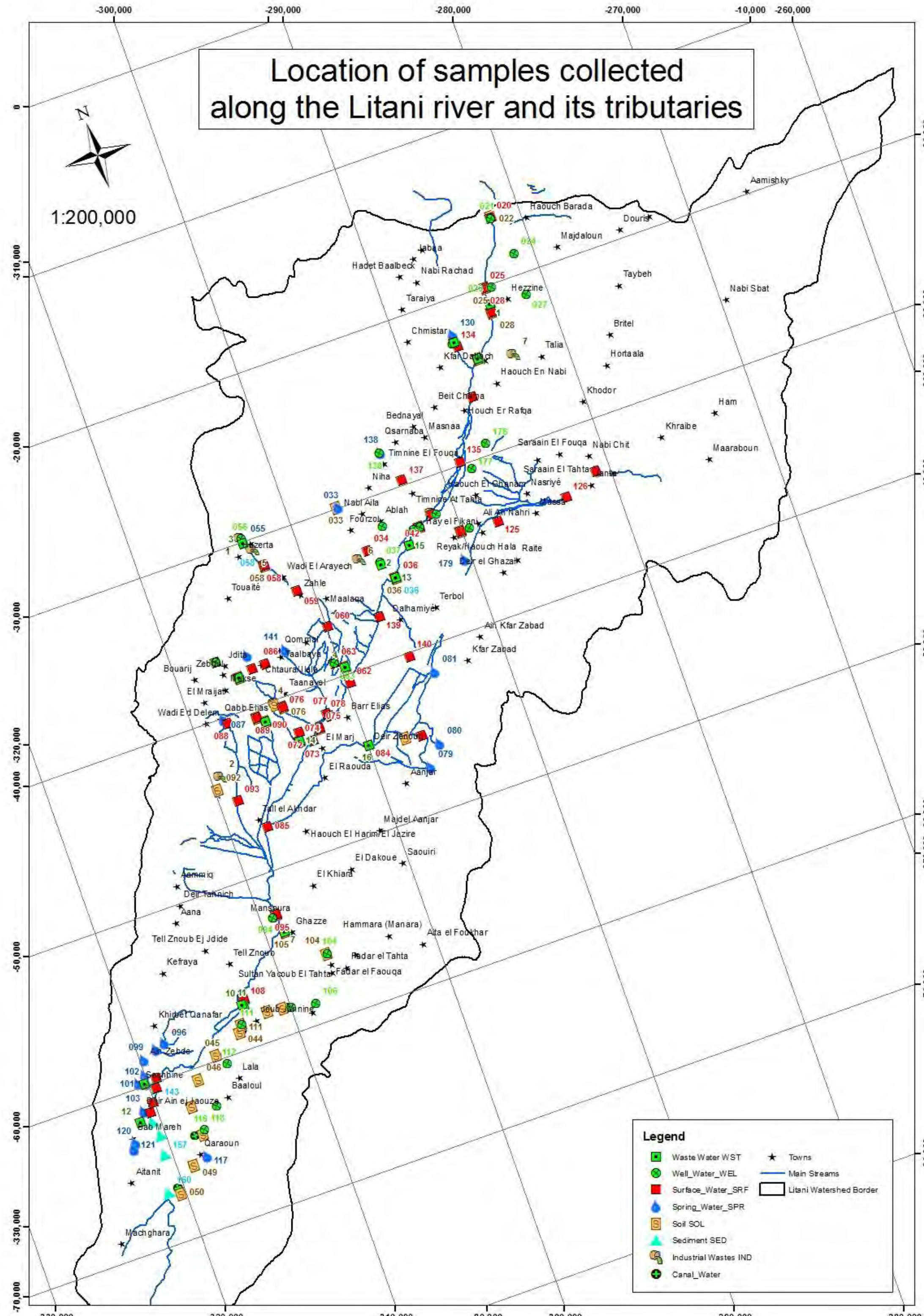
7 – Industrial Results

8 – Soil Results

9 – River sediment Results

The map next page presents all samples with location and type. Finding individual results requires:

- Identifying the number of the sample location on the map; and
- Referring to the corresponding section and tables.



Location and Type of all samples

8.1. SURFACE RESULTS

I. a - Physical Characteristics of Sampled Surface Water within The Upper Litani Basin

Reference	T °C	CND µs/cm	TDS mg/l
20	23	471	330
28		2520	1979
36		1532	1059
42		1959	1358
58	20.6	543	380
59	22.3	336	258
63	16.3	324	235
68		1444	1004
70	15.5	365	252
73		402	278
74		1095	763
76	24.3	564	394
82	19.4	440	305
89	23.9	566	396
90		1304	910
95	28.5	540	376
84		408	282
108		599	420
143		347	242
127	17.1	409	284
134	25.1	348	242
132	25.7	272	187
133	29.4	516	359
145	27.8	366	255
149	28.7	361	252
150	32.1	362	254

Mean	**24**	**707**	**502**
SD	**5**	**577**	**430**
Max	**32**	**2520**	**1979**
Min	**16**	**272**	**187**
EPA standards			**500**
WHO guidelines			**1000**

I.b1 - Chemical Characteristics (Macro Elements) of Sampled Surface Water within The Upper Litani Basin

Reference	pH	DO mg/l	BOD	Salinity mg/L	AIK mg/l as CaCO3	Chlorides mg/l Cl-
20	8	8.51	81	233	180	25
28	7.52	0.66	110	1350	170	325
36	7.91	0.67	1068	753	180	150
42	7.92	0.73	1797	934	180	160
58	8.29	6.42	41	269	180	60
59	8.66	7.2	36	176	180	25
63	7.61	6.59	31	167	150	15
68	7.27	0.38	2530	709	180	310
70	8.13	7.28	28	179	180	15
73	8.15	5	363	197	150	25
74	7.49	2.31	1500	542	180	95
76	7.58	1.88	836	281	180	25
82	7.57	4.04	52	214	150	20
89	7.38	1.66	38	296	180	25
90	7.58	0.99	1564	648	170	160
95	8.09	7.53	64	266	180	30
84	8.33	5.98	1733	201	150	15
108	7.46	6.57	1198	303	180	35
143	8.14	3.63	6.2	169	180	45
127	8.22	6.29	24	203	180	20
134	7.96	6.91	19	167	170	15
132	7.98	4.24	12	259	180	25
133	8.46	9.4	10	243	180	40
145	7.95	5.13	2.5	180	180	30
149	8.21	4.8		174	180	35
150	8.26	6.14		180	180	40
Mean	**7.93**	**4.65**	**548**	**357**	**174**	**68**
SD	**0.37**	**2.72**	**768**	**293**	**11**	**86**
Max	**8.66**	**9.40**	**2530**	**1350**	**180**	**325**
Min	**7.27**	**0.38**	**3**	**167**	**150**	**15**
EPA standards	**6.5-8.5**					**250**
EPA secondary standards						
WHO guidelines	**6.8-8**					**250**

I.b2 - Chemical Characteristics (Macro Elements) of Sampled Surface Water within The Upper

Litani Basin

Reference	NO3-N mg/l	NH3-N mg/l	Orthophosphates mg/l PO4	Sulfates mg/l SO4--	Potassium mg/L as K+	Calcium mg/L as Ca++	Magnesium mg/L as Mg++	Sodium mg/L as Na+	Iron mg/L as Fe
20	3.5	1.8	0.19	8	141	60	56	17	0.01
28	0.7	68.5	56.5	4	33.34	244	5	80	0.64
36	0.5	48.5	80	15	18.54	148	12	55	0.08
42	1.8	34.75	36	41	29.5	120	22	36.3	0.17
58	0.5	3.25	0.66	22	4.1	80	5	21.6	0.06
59	1.1	0.65	0.69	9	1.77	60	12	10	0.07
63	0.7	0.55	0.53	10	0.9	68	10	4	ND
68	3.9	16.5	97.5	ND	19.64	76	27	67	1.15
70	0.2	0.9	0.43	1	0.7	64	15	4.7	0.04
73	0.1	1.75	1.94	13	3.18	68	12	14	0.05
74	0.2	24.25	2.56	90	12	156	12	33.2	0.09
76	0.4	4	1.16	17	10.19	84	22	17	0.03
82	1.9	0.6	0.27	12	1.5	80	22	6.8	0.05
89	1.6	23.5	0.55	50	4.88	100	5	11	0.19
90	4.9	55	10.8	17	17.8	64	15	45.8	0.1
95	0.3	2.2	1.27	29	3.22	88	12	16	0.19
84	0.6	1.2	0.26	30	2	48	36	8	0.1
108	0.7	9	6	10	5.5	220	17	15.8	0.1
143	0.8	0.16	0.48	40	3.23	40	15	16	0.16
127	1.5	1.3	0.1	22	1.7	68	12	7.4	0.08
134	1.7	1.25	0.13	3	1.1	68	7	5.8	0.02
132	0.8	1.25	0.85	4	1.49	68	10	8	ND
133	1.9	6.75	0.33	28	4.7	80	7	16.8	ND
145	0.4	0.26	0.25	38	3.3	52	2	12.6	0.1
149	0.5	0.08	UR	37	3.07	44	10	17	0.03
150	0.8	0.15	0.86	37	2.99	48	7	16	0.09

Mean	**1.23**	**11.85**	**12**	**23**	**13**	**88**	**15**	**22**	**0.16**
SD	**1.21**	**19.19**	**27**	**20**	**28**	**51**	**11**	**20**	**0.25**
Max	**4.90**	**68.50**	**98**	**90**	**141**	**244**	**56**	**80**	**1.15**
Min	**0.10**	**0.08**	**0**	**1**	**1**	**40**	**2**	**4**	**0.01**
EPA standards	**10**								
EPA secondary standards									**0.3**
WHO guidelines	**10**								

I.c1 - Chemical Characteristics (Trace Metals) of Sampled Surface Water within The Upper Litani Basin

Reference	Lead µg/L as Pb	Cadmium µg/L as Cd	Chromium µg/L as Cr	Nickel µg/L as Ni	Copper µg/L as Cu	Zinc µg/L as Zn
20	*	*	*	*	*	*
28	*	*	*	*	*	*
36	*	*	*	*	*	*
42	ND	3.338	5.05	9.245	0.4137	5.3681
58	ND	2.055	ND	2.787	0.8791	25.4054
59	*	*	*	*	*	*
63	*	*	*	*	*	*
68	*	*	*	*	*	*
70	ND	0.591	0.13	3.126	0.6266	24.6765
73	*	*	*	*	*	*
74	ND	1.643	0.39	7.848	0.6266	28.1121
76	*	*	*	*	*	*
82	ND	0.918	ND	0.406	0.5658	16.8955
89	*	*	*	*	*	*
90	ND	8.729	0.48	4.509	0.7392	31.6494
95	*	*	*	*	*	*
84	*	*	*	*	*	*
108	ND	1.643	ND	1.029	2.0015	44.3916
143	*	*	*	*	*	*
127	ND	70.085	ND	0.028	1.022	0.5506
134	ND	4.973	0.64	0.127	0.5506	22.0206
132	*	*	*	*	*	*
133	ND	7.268	0.37	3.602	0.8882	19.5965
145	ND	8.068	ND	1.013	0.8669	25.7557
149	*	*	*	*	*	*
150	*	*	*	*	*	*

Mean	**0.00**	**9.94**	**1.18**	**3.07**	**0.83**	**22**
SD	**0.00**	**20.17**	**1.90**	**3.11**	**0.43**	**12**
Max	**0.00**	**70.09**	**5.05**	**9.25**	**2.00**	**44**
Min	**0.00**	**0.59**	**0.13**	**0.03**	**0.41**	**1**
EPA standards		**0.005**	**0.1**			
EPA Secondary standards					**1**	**5**
WHO	**0.01**	**0.003**	**0.05**	**0.07**	**2**	

*: 20% of the samples were tested

I.c2 - Chemical Characteristics (Trace Metals) of Sampled Surface Water within The Upper Litani Basin

Reference	Aluminum μg/L as Al	Barium μg/L as Ba	Cobalt μg/L as Co	Boron μg/L as B	Manganese mg/L as Mn	Molybdenum μg/L as Mo	Mercury μg/L as Hg	Arsenic μg/L as As
20	*	*	*	*	0.027	*	*	*
28	*	*	*	*	0.233	*	*	*
36	*	*	*	*	0.117	*	*	*
42	44.5	282.6	0.4	ND	0.031	1.63	ND	ND
58	25.1	296.6	0.1434	ND	0.036	1.94	ND	ND
59	*	*	*	*	0.035	*	*	*
63	*	*	*	*	0.039	*	*	*
68	*	*	*	*	ND	*	*	*
70	12.8	30.7	0.23	ND	0.041	2.11	ND	ND
73	*	*	*	*	0.056	*	*	*
74	61.8	302.7	0.12	ND	0.077	2.55	ND	ND
76	*	*	*	*	0.042	*	*	*
82	14.2	285.5	0.56	ND	0.043	4.15	ND	ND
89				*	0.091	*	*	*
90	43.7	315.7	0.2	ND	0.175	1.67	ND	ND
95	*	*	*	*	0.071	*	*	*
84	*	*	*	*	0.04	*	*	*
108	24.1	301.5	0.35	ND	0.272	2.59	ND	ND
143	*	*	*	*	0.05	*	*	*
127	132.1	310.6	0.11	ND	0.051	2.52	ND	ND
134	27	380.9	0.3	ND	0.049	1.63	ND	ND
132	*	*	*	*	0.046	*	*	*
133	47	387.5	0.22	ND	0.064	2.76	ND	ND
145	42.5	110.1	0.16	ND	0.053	2.52	ND	ND
149	*	*	*	*	0.009	*	*	*
150	*	*	*	*	0.054	*	*	*
Mean	**43**	**273**	**0.25**		**0.07**	**2.37**		**0**
SD	**33**	**108**	**0.14**		**0.06**	**0.73**		**0**
Max	**132**	**388**	**0.56**		**0.27**	**4.15**		**0**
Min	**13**	**31**	**0.11**		**0.01**	**1.63**		**0**
EPA standards		**2**						**0.01**
EPA Secondary standards	**0.005-0.2**				**0.05**			
WHO	**0.2**	**0.7**		**0.5**	**0.4**	**0.07**		**0.01**

*: 20% of the samples were tested

I.d - Microbiological Characteristics of Sampled Surface Water within The Upper Litani Basin

Reference	Total Coliforms/ 100ml	Fecal coliforms/ 100 ml	Strep Fecalis/ 100ml
20	1	0	0
28	0	0	0
36	0	0	0
42	0	0	0
58	0	0	0
59	TNTC	5	0
63	TNTC	TNTC	0
68	TNTC	TNTC	0
70	0	0	0
73	TNTC	70	0
74	TNTC	42	0
76	0	0	0
82	TNTC	3	0
89	0	0	0
90	90	0	0
95	TNTC	40	0
84	TNTC	32	0
108	TNTC	0	0
143	TNTC	4	0
127	TNTC	65	0
134	TNTC	TNTC	0
132	TNTC	TNTC	6
133	TNTC	0	0
145	TNTC	0	0
149	TNTC	1	0
150	0	0	0

8.2. SPRING RESULTS

II.a - Physical Characteristics of Sampled Spring Water along The Upper Litani Basin

Reference	T °C	CND µs/cm	TDS mg/l
33	19.5	306	212
55	24.9	264	184
69	15.6	351	245
79	19	427	291
80	19.7	453	317
87	17.9	238	172
96	19.5	372	255
98	18.3	463	324
99	18.5	527	368
101	17.7	487	323
102	25.9	470	324
103	19.3	352	254
117	22.3	575	396
120	15.7	361	245
121	15.5	338	247
127	18.9	430	299
130	21.5	403	279
179		565	392

Mean	**19.39**	**410**	**285**
SD	**2.92**	**96**	**65**
Max	**25.90**	**575**	**396**
Min	**15.50**	**238**	**172**
EPA standards			**500**
WHO guidelines			**1000**

II.b1- Chemical Characteristics (Macro Elements) of Sampled Spring Water along The Upper Litani Basin

Reference	pH	DO mg/l	BOD	Salinity mg/L	AlK mg/l as CaCO3	Chlorides mg/l Cl-	NO3-N mg/l
33	7.71	7.76		140	180	15	1.1
55	8.07	6.14	36	131	150	20	0.6
69	7.64	7.59	13	176	150	10	1.4
79	7.72	6.46		206	180	10	2
80	7.62	7.36		227	180	10	1.7
87	8.48	7.5		122	180	10	1
96	7.41	5.82		184	190	35	0.8
98	7.68	5.64		223	170	25	0.8

99	8.2	5.62		262	180	15	0.3
101	7.35	5.7		212	150	20	0.6
102	7.56	5.33		225	180	20	0.4
103	7.62	5.63		180	170	20	0.3
117	7.5	5.75		291	150	20	0.2
120	8.05	7.17		171	150	15	0.5
121	8.33	7.8		174	150	10	0.5
127	7.46	6.36		212	150	15	1
130	7.51	6.66		202	180	20	2.8
179	8.32			278	160	30	17
Mean	**7.79**	**6.49**	**24.50**	**201**	**167**	**17.78**	**1.83**
SD	**0.35**	**0.87**	**16.26**	**47**	**15**	**7.12**	**3.84**
Max	**8.48**	**7.80**	**36.00**	**291**	**190**	**35.00**	**17.00**
Min	**7.35**	**5.33**	**13.00**	**122**	**150**	**10.00**	**0.20**
EPA standards	**6.5-8.5**					**250**	**10**
EPA secondary standards							
WHO guidelines	**6.8-8**					**250**	**10**

II.b2- Chemical Characteristics (Macro Elements) of Sampled Spring Water along The Upper Litani Basin

Reference	**NH3-N mg/l**	**Orthophosphates mg/l PO4**	**Sulfates mg/l SO4--**	**Potassium mg/L as K+**	**Calcium mg/L as Ca++**	**Magnesium mg/L as Mg++**	**Sodium mg/L as Na+**	**Iron mg/L as Fe**
33	UR	0.34	2	0.31	60	15	5	0.04
55	UR	0.36	4	0.27	44	12	3	0.03
69	UR	0.76	9	0.6	48	17	4.7	0.02
79	0.15	0.38	10	1.06	64	19	6	0.01
80	0.21	0.17	11	0.9	64	24	6	0.01
87	UR	0.21	12	0.3	60	7	4.2	0.05
96	0.2	0.07	2	0.7	64	29	5	0.08
98	0.15	0.09	29	0.39	84	10	4	0.07
99	0.16	0.16	56	0.31	104	24	4	0.02
101	0.29	0.63	25	1.41	88	19	6	ND
102	0.17	0.45	24	0.2	84	10	4	0.04
103	0.17	0.4	19	0.27	64	15	4	0.05
117	0.85	0.62	9	1.18	72	15	8	0.04
120	1.05	0.3	29	0.3	60	5	3.7	0.03
121	1.36	0.1	35	0.27	68	5	4	0.05
127	0.47	0.36	19	1.27	68	10	7	0.01
130	0.17	0.04	9	1.3	68	10	6.8	0.03
179	0.27	2.9	21	1.61	120	29	8	ND
Mean	**0.41**	**0.46**	**18.06**	**0.70**	**71.33**	**15.28**	**5.19**	**0.04**
SD	**0.39**	**0.64**	**13.66**	**0.48**	**18.72**	**7.52**	**1.51**	**0.02**
Max	**0.15**	**2.90**	**56.00**	**1.61**	**120.00**	**29.00**	**8.00**	**0.08**

Min	**1.36**	**0.04**	**2.00**	**0.20**	**44.00**	**5.00**	**3.00**	**0.01**
EPA standards								
EPA secondary standards								**0.3**
WHO guidelines								

II.c1 - Chemical Characteristics (Trace Metals) of Sampled Spring Water along The Upper Litani Basin

Reference	Lead μg/L as Pb	Cadmium μg/L as Cd	Chromium μg/L as Cr	Nickel μg/L as Ni	Copper μg/L as Cu	Zinc μg/L as Zn	Aluminum μg/L as Al
33	*	*	*	*	*	*	*
55	*	*	*	*	*	*	*
69	ND	1.21	ND	ND	1.1559	32.955	21.6
79	*	*	*	*	*	*	*
80	*	*	*	*	*	*	*
87	ND	16.614	0.19	0.307	0.7422	19.676	22.7
96	*	*	*	*	*	*	*
98	*	*	*	*	*	*	*
99	*	*	*	*	*	*	*
101	*	*	*	*	*	*	*
102	*	*	*	*	*	*	*
103	*	*	*	*	*	*	*
117	*	*	*	*	*	*	*
120	ND	8.803	ND	2.566	0.5049	9.6344	15.9
121	*	*	*	*	*	*	*
127	*	*	*	*	*	*	*
130	ND	2.826	ND	0.946	0.4563	11.629	23.4
179	*	*	*	*	*	*	*
Mean	**0.00**	**7.36**	**0.19**	**1.27**	**0.71**	**18.47**	**20.90**
SD	**0.00**	**6.98**		**1.16**	**0.32**	**10.58**	**3.41**
Max	**0.00**	**16.61**	**0.19**	**2.57**	**1.16**	**32.95**	**23.40**
Min	**0.00**	**1.21**	**0.19**	**0.31**	**0.46**	**9.63**	**15.90**
EPA standards		**0.005**	**0.1**				
EPA Secondary standards					**1**	**5**	**0.005-0.2**
WHO	**0.01**	**0.003**	**0.05**	**0.07**	**2**		**0.2**

*: 20% of the samples were tested

II.c2 - Chemical Characteristics (Trace Metals) of Sampled Spring Water along The Upper Litani Basin

Reference	Barium µg/L as Ba	Cobalt µg/L as Co	Boron µg/L as B	Manganese mg/L as Mn	Molybdenum µg/L as Mo	Mercury µg/L as Hg	Arsenic µg/L as As
33	*	*	*	0.115	*	*	*
55	*	*	*	0.077	*	*	*
69	118.4	0.32	ND	0.087	1.7	ND	ND
79	*	*	*	0.072	*	*	*
80	*	*	*	0.083	*	*	*
87	180.4	0.15	ND	0.106	2.35	ND	ND
96	*	*	*	0.118	*	*	*
98	*	*	*	0.059	*	*	*
99	*	*	*	0.054	*	*	*
101	*	*	*	0.105	*	*	*
102	*	*	*	0.048	*	*	*
103	*	*	*	0.077	*	*	*
117	*	*	*	0.048	*	*	*
120	191.3	0.42	ND	0.04	1.57	ND	ND
121	*	*	*	0.045	*	*	*
127	*	*	*	0.048	*	*	*
130	178.2	0.17	ND	0.048	3.03	ND	ND
179	*	*	*	0.069	*	*	*
Mean	**167**	**0.27**		**0.07**	**2.16**		
SD	**33**	**0.13**		**0.03**	**0.67**		
Max	**191**	**0.42**		**0.12**	**3.03**		
Min	**118**	**0.15**		**0.04**	**1.57**		
EPA standards	**2**					**0.002**	
EPA Secondary standards				**0.05**			
WHO	**0.7**		**0.5**	**0.4**	**0.07**	**0.006**	**0.01**

II.d - MicrobiologicalCharacteristics of Sampled Spring Water along The Upper Litani Basin

Reference	Total Coliforms/ 100ml	Fecal coliforms/ 100 ml	Strep Fecalis/ 100ml
33	0	0	0
55	1	0	0
69	TNTC	90	0
79	7	0	0
80	37	0	0
87	TNTC	TNTC	5
96	TNTC	16	9
98	TNTC	TNTC	0
99	TNTC	64	2
101	TNTC	TNTC	25
102	0	0	0
103	10	2	0
117	TNTC	94	1
120	TNTC	62	0
121	TNTC	42	0
127	TNTC	74	22
130	TNTC	4	0
179	0	0	0

8.3. WELL RESULTS

III.a - Physical Characteristics of Sampled Well Water along The Upper Litani Basin

Reference	T °C	CND µs/cm	TDS mg/l
21	21.1	461	310
24	18.5	549	370
26		755	525
27	22.6	549	380
37	20.5	912	550
40	26.3	507	370
56	14.8	248	170
63	23	575	370
65	17.4	299	210
94	29.7	646	454
104	21.1	513	354
106	20.3	355	245
107	19.7	297	206

111	23.1	575	400
116	26.3	468	312
118	28.6	471	325
124	22.5	544	374
129	19.9	532	384
131	19.4	592	416
138	19.4	290	200
180		507	353
176		645	448
177		759	529
178		756	525
181		1236	863

Mean	**21.80**	**562**	**386**
SD	**3.78**	**214**	**145**
Max	**29.70**	**1236**	**863**
Min	**14.80**	**248**	**170**
EPA standards			**500**
WHO guidelines			**1000**

III.b1 - Chemical Characteristics (Macro Elements) of Sampled Well Water along The Upper Litani Basin

Reference	pH	DO mg/l	BOD	Salinity mg/L	AlK mg/l as CaCO3	Chlorides mg/l Cl-	NO3-N mg/l
21	6.98			226	190	30	0.8
24	8.72			263	180	35	9.7
26	8.33			370	140	65	41
27	7.47			283	180	40	7.9
37	7.05	2.69		454	190	70	0.2
40	7.84	4.53		260	180	20	3.1
56	8.23	7.75		121	60	15	0.9
63	7.47	4.25		290	180	15	4.4
65	8.01	5.73		207	150	20	0.8
94	7.51	4.1		324	180	25	5.5
104	7.52	5.94		255	180	35	6
106	7.87	6.22		168	150	15	1.6
107	7.50	6.99		146	180	20	0.2
111	7.40	4.99		284	190	30	4.5
116	7.76	5.35		222	180	20	3.7
118	7.46	4.5		237	180	25	2.1
124	7.76	6.12		270	180	20	7
129	7.58	6.54		272	180	15	2.9
131	7.67	6.12		280	180	20	4
138	7.80	7.55		140	170	15	0.8

180	8.40			249	190	25	0.45
176	8.21			318	196	50	10.1
177	7.70			375	156	60	30
178	7.96			372	202	70	9.6
181	7.73			614	284	130	10.5
Mean	**7.76**	**5.59**		**280**	**177**	**35.40**	**6.71**
SD	**0.40**	**1.36**		**105**	**35**	**26.57**	**9.42**
Max	**8.72**	**7.75**		**614**	**284**	**130.00**	**41.00**
Min	**6.98**	**2.69**		**121**	**60**	**15.00**	**0.20**
EPA standards	**6.5-8.5**					**250**	**10**
EPA secondary standards							
WHO guidelines	**6.8-8**					**250**	**10**

III.b2 - Chemical Characteristics (Macro Elements) of Sampled Well Water along The Upper Litani Basin

Reference	NH3-N mg/l	Orthophosphates mg/l PO4	Sulfates mg/l SO4--	Potassium mg/L as K+	Calcium mg/L as Ca++	Magnesium mg/L as Mg++	Sodium mg/L as Na+	Iron mg/L as Fe
21	0.13	0.26	7	1.45	60	12	11	0.02
24	0	0.65	2	2.12	92	7	6	0.11
26	0	0.62	19	0.43	128	19	12	0.16
27	0	0.23	1	0.66	96	5	5	0.16
37	0	0.54	57	6.1	140	27	16.3	0.02
40	0.11	0.39	12	1.92	84	10	10	0.03
56	0.26	0.47	1	0.78	52	10	1	0.03
63	0.17	0.65	7	1.6	88	19	7.4	0.16
65	0.18	1	8	0.55	60	5	4	0.02
94	0.24	0.35	19	0.55	64	29	11	0.03
104	0.29	0.33	12	2.7	84	7	10	0.02
106	0.2	0.29	1	0.82	64	7	6	ND
107	0.17	0.3	1	0.11	56	7	4	0.07
111	0.18	0.4	20	1.1	88	12	15	ND
116	0.35	0.38	6	0.7	68	12	11	0.02
118	0.32	0.24	12	0.4	76	10	7.4	0.12
124	0.09	0.31	7	0.11	80	7	1.36	0.03
129	0.28	0.2	6	1.33	92	17	13	ND
131	0.51	0.39	6	0.9	96	27	8	0.02
138	0.6	0.2	5	0.35	68	5	3	0.04
180	0.46	6.43	4	0.96	92	29	9	0.01
176	0.47	4.06	14	0.66	144	19	12	0.07
177	0.36	4.76	22	0.66	160	12	9	ND
178	0.33	6.32	18	1.06	140	85	11	ND
181	0.36	0.11	64	0.66	236	10	19	0.03
Mean	**0.24**	**1.20**	**13.24**	**1.15**	**96.32**	**16.36**	**8.90**	**0.06**
SD	**0.17**	**1.92**	**15.66**	**1.21**	**41.71**	**16.26**	**4.52**	**0.05**

Max	**0.60**	**6.43**	**64.00**	**6.10**	**236**	**85**	**19**	**0.16**
Min	**0.00**	**0.11**	**1.00**	**0.11**	**52**	**5**	**1**	**0.01**
EPA standards								
EPA secondary standards								**0.3**
WHO guidelines								

III.c1 - Chemical Characteristics (Tace Metals) of Sampled Well Water along The Upper Litani Basin

Reference	Lead µg/L as Pb	Cadmium µg/L as Cd	Chromium µg/L as Cr	Nickel µg/L as Ni	Copper µg/L as Cu	Zinc µg/L as Zn
21	*	*	*	*	*	*
24	*	*	*	*	*	*
26	*	*	*	*	*	*
27	*	*	*	*	*	*
37	ND	1.139	1.1	4.006	1.5209	19.3083
40	*	*	*	*	*	*
56	*	*	*	*	*	*
63	ND	1.895	ND	0.139	0.7969	35.9156
65	*	*	*	*	*	*
94	*	*	*	*	*	*
104	ND	3.42	ND	0.918	0.4715	8.5156
106	*	*	*	*	*	*
107	*	*	*	*	*	*
111	*	*	*	*	*	*
116	*	*	*	*	*	*
118	ND	3.601	1.36	1.084	0.9247	19.658
124	*	*	*	*	*	*
129	*	*	*	*	*	*
131	*	*	*	*	*	*
138	*	*	*	*	*	*
180	*	*	*	*	*	*
176	*	*	*	*	*	*
177	*	*	*	*	*	*
178	*	*	*	*	*	*
181	*	*	*	*	*	*
Mean		**2.51**	**1.23**	**1.54**	**0.93**	**20.85**
SD		**1.19**	**0.18**	**1.70**	**0.44**	**11.30**
Max		**3.60**	**1.36**	**4.01**	**1.52**	**35.92**
Min		**1.14**	**1.10**	**0.14**	**0.47**	**8.52**
EPA standards		**0.005**	**0.1**			
EPA Secondary standards					**1**	**5**

WHO	**0.01**	**0.003**	**0.05**	**0.07**	**2**	

*: 20% of the samples were tested

III.c2 - Chemical Characteristics (Tace Metals) of Sampled Well Water along The Upper Litani Basin

Reference	**Aluminum µg/L as Al**	**Barium µg/L as Ba**	**Cobalt µg/L as Co**	**Boron µg/L as B**	**Manganese mg/L as Mn**	**Molybdenum µg/L as Mo**	**Mercury µg/L as Hg**	**Arsenic µg/L as As**
21	*	*	*	*	0.038	*	*	*
24	*	*	*	*	0.028	*	*	*
26	*	*	*	*	0.042	*	*	*
27	*	*	*	*	0.054	*	*	*
37	26	172.1	0.25	ND	0.068	1.7	ND	ND
40	*	*	*	*	0.063	*	*	*
56	*	*	*	*	0.029	*	*	*
63	48.4	182.7	0.19	ND	0.039	2.25	ND	ND
65	*	*	*	*	0.035	*	*	*
94	*	*	*	*	0.04	*	*	*
104	41	162.5	0.29	ND	0.041	2.01	ND	ND
106	*	*	*	*	0.05	*	*	*
107	*	*	*	*	0.035	*	*	*
111	*	*	*	*	0.036	*	*	*
116	*	*	*	*	0.041	*	*	*
118	24.3	189.9	0.88	ND	0.153	5.72	ND	ND
124	*	*	*	*	0.05	*	*	*
129	*	*	*	*	0.04	*	*	*
131	*	*	*	*	0.047	*	*	*
138	*	*	*	*	0.055	*	*	*
180	*	*	*	*	0.048	*	*	*
176	*	*	*	*	0.066	*	*	*
177	*	*	*	*	0.027	*	*	*
178	*	*	*	*	0.079	*	*	*
181	*	*	*	*	0.54	*	*	*
Mean	**34.93**	**177**	**0.40**		**0.07**	**2.92**		
SD	**11.71**	**12**	**0.32**		**0.10**	**1.88**		
Max	**48.40**	**190**	**0.88**		**0.54**	**5.72**		
Min	**24.30**	**163**	**0.19**		**0.03**	**1.70**		
EPA standards		**2**					**0.002**	**0.01**
EPA Secondary standards	**0.005-0.2**				**0.05**			
WHO	**0.2**	**0.7**		**0.5**	**0.4**	**0.07**	**0.006**	**0.01**

*: 20% of the samples were tested

III.d - Microbiological Characteristics of Sampled Well Water along The Upper Litani Basin

Reference	Total Coliforms/ 100ml	Fecal coliforms/ 100 ml	Strep Fecalis/ 100ml
21	0	0	0
24	0	0	0
26	0	0	0
27	8	0	0
37	1	0	0
40	TNTC	148	0
56	0	0	0
63	11	0	0
65	0	0	0
94	0	0	0
104	0	0	0
106	0	0	0
107	TNTC	32	6
111	0	0	0
116	0	0	0
118	0	0	0
124	24	0	0
129	TNTC	TNTC	1
131	TNTC	TNTC	0
138	6	0	0
180	0	0	0
176	0	0	0
177	0	0	0
178	0	0	0
181	0	0	0

8.4. LAKE RESULTS

IV.a - Physical Characteristics of Sampled Water from Qaraoun Lake

Reference	T °C	CND µs/cm	TDS mg/l
151	34.2	371	256
152	34.7	373	248
153	33.6	350	244
154	32.2	337	233
155		328	229
156		328	226
157		325	232
158		321	221
159		341	238
160		323	224
Mean	**33.68**	**340**	**235**
SD	**1.08**	**19.21**	**11.29**
Max	**34.70**	**373**	**256**
Min	**32.20**	**321**	**221**
EPA standards			**500**
WHO guidelines			**1000**

IV.b1 - Chemical Characteristics (Macro Elements) of Sampled Water from Qaraoun Lake

Reference	pH	DO mg/l	BOD	Salinity mg/L	AlK mg/l as CaCO3	Chlorides mg/l Cl-	NO3-N mg/l	NH3-N mg/l
151	8.2	7.22		184	170	35	1.1	0.13
152	8.23	8.08		177	180	35	1	0.15
153	8.32	8.83		174	180	35	0.8	0.19
154	8.29	9.41	3.3	165	180	35	1.2	0.15
155	8.31			164	180	35	0.8	0.14
156	8.24			159	180	35	0.8	0.23
157	8.31			164	170	35	0.8	0.18
158	8.32			158	180	30	0.8	0.18
159	8.21			167	180	35	0.9	0.27
160	8.23		2	158	180	30	1.1	UR
Mean	**8.27**	**8.39**	**2.65**	**167**	**178**	**34**	**0.93**	**0.18**
SD	**0.05**	**0.95**	**0.92**	**8.73**	**4.22**	**2.11**	**0.16**	**0.05**
Max	**8.32**	**9.41**	**3.30**	**184**	**180**	**35**	**1.20**	**0.27**
Min	**8.20**	**7.22**	**2.00**	**158**	**170**	**30**	**0.80**	**0.13**
EPA standards	**6.5-8.5**					**250**	**10**	

EPA secondary standards								
WHO guidelines	**6.8-8**					**250**	**10**	

IV.b2 - Chemical Characteristics (Macro Elements) of Sampled Water from Qaraoun Lake

Reference	**Orthophosphates mg/l PO4**	**Sulfates mg/l SO4--**	**Potassium mg/L as K+**	**Calcium mg/L as Ca++**	**Magnesium mg/L as Mg++**	**Sodium mg/L as Na+**	**Iron mg/L as Fe**
151	UR	38	3.14	28	19	19	0.01
152	UR	36	3.14	40	7	19	0.06
153	0.08	39	3.26	48	5	20	0.1
154	0.14	38	3.3	40	10	12.6	0.07
155	UR	37	3.03	40	7	18	0.06
156	0.08	37	3.03	44	12	18	0.02
157	0.25	37	3.03	40	7	17	0.11
158	0.33	37	3.03	40	7	18	0.07
159	0.22	36	2.95	40	10	17	ND
160	0.06	36	3.3	52	12	12.6	0.05
Mean	**0.17**	**37.10**	**3.12**	**41.20**	**9.60**	**17.12**	**0.06**
SD	**0.10**	**0.99**	**0.13**	**6.27**	**4.06**	**2.55**	**0.03**
Max	**0.33**	**39**	**3.30**	**52**	**19**	**20.00**	**0.11**
Min	**0.06**	**36**	**2.95**	**28**	**5**	**12.60**	**0.01**
EPA standards							
EPA secondary standards							**0.3**
WHO guidelines							

IV.c1 - Chemical Characteristics (Trace Metals) of Sampled Water from Qaraoun Lake

Reference	**Lead µg/L as Pb**	**Cadmium µg/L as Cd**	**Chromium µg/L as Cr**	**Nickel µg/L as Ni**	**Copper µg/L as Cu**	**Zinc µg/L as Zn**
151	ND	8.12	ND	0.97	1.7034	51.23
152	ND	9.15	ND	0.43	2.2631	37.97
153	ND	17.06	ND	0.11	0.8334	28.47

154	ND	21.92	ND	0.016	0.4989	10.43
155	ND	12.41	ND	0.1	0.4502	30.41
156	ND	16.42	ND	0.07	0.6874	6.227
157	ND	10.5	ND	0.09	3.7505	40.22
158	ND	8.41	ND	0.081	0.5597	34.98
159	ND	1.01	ND	0.091	1.0616	36.88
160	ND	0.762	0.84	0.0955	0.8608	36.84

Mean	**0.00**	**10.58**	**0.84**	**0.21**	**1.27**	**31.37**
SD	**0.00**	**6.74**		**0.29**	**1.05**	**13.62**
Max	**0.00**	**21.92**	**0.84**	**0.97**	**3.75**	**51.23**
Min	**0.00**	**0.76**	**0.84**	**0.02**	**0.45**	**6.23**
EPA standards		**0.005**	**0.1**			
EPA Secondary standards					**1**	**5**
WHO	**0.01**	**0.003**	**0.05**	**0.07**	**2**	

IV.c2- Chemical Characteristics (Trace Metals) of Sampled Water from Qaraoun Lake

Reference	Aluminum µg/L as Al	Barium µg/L as Ba	Cobalt µg/L as Co	Boron µg/L as B	Manganese mg/L as Mn	Molybdenum µg/L as Mo	Mercury µg/L as Hg	Arsenic µg/L as As
151	52.1	158	0.27	ND	0.054	2.□8	ND	ND
152	54.4	129	□.12	ND	0.06	2.11	ND	ND
153	42.4	160	0.24	ND	0.041	2.45	ND	ND
154	94.2	125.9	0.22	ND	0.055	2.11	ND	ND
155	51.7	277	0.15	ND	0.022	1.87	ND	ND
156	64.1	240	0.22	ND	0.028	1.91	ND	ND
157	60.1	232	0.15	ND	0.035	1.5	ND	ND
158	67.6	238	0.18	ND	0.024	3.13	ND	ND
159	58.3	289	0.12	ND	0.026	2.31	ND	ND
160	62.9	276	0.12	ND	0.032	2.08	ND	ND
Mean	**61**	**212**	**0.18**		**0.04**	**2.19**		
SD	**14**	**63**	**0.06**		**0.01**	**0.43**		
Max	**94**	**289**	**0.27**		**0.06**	**3.13**		
Min	**42**	**126**	**0.12**		**0.02**	**1.50**		
EPA standards		**2**					**0.002**	**0.01**
EPA Secondary standards	**0.005-0.2**				**0.05**			
WHO	**0.2**	**0.7**		**0.5**	**0.4**	**0.07**	**0.006**	**0.01**

IV.d- Microbiological Characteristics of Sampled Water from Qaraoun Lake

Reference	Total Coliforms/ 100ml	Fecal coliforms/ 100 ml	Strep Fecalis/ 100ml
151	TNTC	TNTC	0
152	TNTC	TNTC	0
153	0	0	0
154	0	0	0
155	0	0	0
156	0	0	0
157	TNTC	TNTC	0
158	TNTC	6	0
159	TNTC	TNTC	0
160	0	0	0

8.5. CANAL 900 RESULTS

V.a - Physical Characteristics of Sampled Water from Canal 900

Reference	T °C	CND µs/cm	TDS mg/l
43	24.5	470	326
45	24	493	343
48	22.3	497	347
49	24.1	490	350
50	20.9	521	363
51	29.5	476	331
53	25.6	459	319
Mean	**24.41**	**487**	**340**
SD	**2.72**	**20**	**15**
Max	**29.50**	**521**	**363**
Min	**20.90**	**459**	**319**
EPA standards			**500**
WHO guidelines			**1000**

V.b1 - Chemical Characteristics (Macro Elements) of Sampled Water from Canal 900

Reference	pH	DO mg/l	BOD	Salinity mg/L	AIK mg/l as CaCO3	Chlorides mg/l Cl-	NO3-N mg/l	NH3-N mg/l
43	7.81	5.74	14	240	170	30	1.2	0.25
45	7.67	4.59	7	240	170	30	1.6	0.26
48	7.51	4.06	10	246	180	35	1.6	0.55
49	7.82	5.32	6	247	170	35	1.9	0.65
50	7.51	1.59	8	258	170	35	1.4	0.53
51	7.9	6.86	7	228	170	40	0.8	0.55
53	7.74	6.41	11	227	170	35	1.2	0.37
Mean	**7.71**	**4.94**	**9**	**241**	**171**	**34.29**	**1.39**	**0.45**
SD	**0.15**	**1.77**	**2.83**	**10.93**	**3.78**	**3.45**	**0.36**	**0.16**
Max	**7.90**	**6.86**	**14**	**258**	**180**	**40**	**1.90**	**0.65**
Min	**7.51**	**1.59**	**6**	**227**	**170**	**30**	**0.80**	**0.25**
EPA standards	**6.5-8.5**					**250**	**10**	
EPA secondary standards								
WHO guidelines	**6.8-8**					**250**	**10**	

V.b2 - Chemical Characteristics (Macro Elements) of Sampled Water from Canal 900

Reference	Orthophosphates mg/l PO4	Sulfates mg/l SO4--	Potassium mg/L as K+	Calcium mg/L as Ca++	Magnesium mg/L as Mg++	Sodium mg/L as Na+	Iron mg/L as Fe
43	0.46	36	3.7	72	29	25	0.05
45	0.67	36	3.3	64	22	24	0.03
48	0.36	34	3.14	80	22	25	0.07
49	0.55	34	2.95	72	24	23	0.13
50	0.69	35	3.4	72	5	12.1	0.3
51	0.24	37	3.9	76	24	12.1	0.17
53	0.33	35	3.34	76	7	24	0.11
Mean	**0.47**	**35.29**	**3.39**	**73.14**	**19**	**20.74**	**0.12**
SD	**0.17**	**1.11**	**0.32**	**5.01**	**9.20**	**5.94**	**0.09**
Max	**0.69**	**37.00**	**3.90**	**80**	**29**	**25**	**0.30**
Min	**0.24**	**34.00**	**2.95**	**64**	**5**	**12.10**	**0.03**
EPA standards							
EPA secondary standards							**0.3**
WHO guidelines							

V.c1 - Chemical Characteristics (Trace Metals) of Sampled Water from Canal 900

Reference	Lead µg/L as Pb	Cadmium µg/L as Cd	Chromium µg/L as Cr	Nickel µg/L as Ni	Copper µg/L as Cu	Zinc µg/L as Zn	Aluminum µg/L as Al
43	*	*	*	*	*	*	*
45	*	*	*	*	*	*	*
48	*	*	*	*	*	*	*
49	*	*	*	*	*	*	*
50	ND	0.396	ND	1.526	0.602	39.37	59.5
51	ND	20.277	ND	1.708	1.548	29.9	124
53	*	*	*	*	*	*	*
Mean		**10.34**		**1.62**	**1.08**	**35**	**92**
SD		**14.06**		**0.13**	**0.67**	**7**	**46**
Max		**20.28**		**1.71**	**1.55**	**39**	**124**
Min		**0.40**		**1.53**	**0.60**	**30**	**60**
EPA standards		**0.005**	**0.1**				
EPA Secondary standards					**1**	**5**	**0.005-0.2**
WHO	**0.01**	**0.003**	**0.05**	**0.07**	**2**		**0.2**

*: 20% of the samples were tested

V.c2 - Chemical Characteristics (Trace Metals) of Sampled Water from Canal 900

Reference	Barium µg/L as Ba	Cobalt µg/L as Co	Boron µg/L as B	Manganese mg/L as Mn	Molybdenum µg/L as Mo	Mercury µg/L as Hg	Arsenic µg/L as As
43	*	*	*	0.083	*	*	*
45	*	*	*	0.042	*	*	*
48	*	*	*	0.044	*	*	*
49	*	*	*	0.089	*	*	*
50	111.3	0.19	ND	0.068	2.59	ND	ND
51	121	0.08	ND	0.032	2.31	ND	ND
53	*	*	*	0.127	*	*	*
Mean	**116**	**0.14**		**0.07**	**2.45**		
SD	**7**	**0.08**		**0.03**	**0.20**		
Max	**121**	**0.19**		**0.13**	**2.59**		
Min	**111**	**0.08**		**0.03**	**2.31**		
EPA standards	**2**					**0.002**	**0.01**
EPA Secondary standards				**0.05**			
WHO	**0.7**		**0.5**	**0.4**	**0.07**	**0.006**	**0.01**

*: 20% of the samples were tested

V.d - Microbiolgical Characteristics of Sampled Water from Canal 900

Reference	Total Coliforms/ 100ml	Fecal coliforms/ 100 ml	Strep Fecalis/ 100ml
43	TNTC	0	0
45	TNTC	0	0
48	TNTC	0	0
49	TNTC	0	0
50	TNTC	0	0
51	TNTC	0	0
53	TNTC	0	0

8.6. WASTEWATER RESULTS

VI.a - Physical Characteristics of Sampled Domestic Wastewater along The Upper Litani Basin

Reference	T °C	CND µs/cm	TDS mg/l
29		1352	943
38		912	636
57		947	660
61		913	637
90		2280	1580
105		1179	822
101		939	655
36		1532	1059
42		1959	1358
73		402	278
84		408	282
134	25.1	348	242
Mean	**25.10**	**1098**	**763**
SD		**606**	**420**
Max	**25.10**	**2280**	**1580**
Min	**25.10**	**348**	**242**

VI.b1 - Chemical Characteristics (Macro Elements) of Sampled Domestic Wastewater along The Upper Litani Basin

Reference	pH	DO mg/l	BOD	Salinity mg/L	AlK mg/l as CaCO3	Chlorides mg/l Cl-	NO3-N mg/l	NH3-N mg/l
29	7.85	0.67	50	671	530	150	180	54
38	7.95	1.1	1215	453	300	140	20	0.74
57	7.58	0.62	964	469	300	150	12.5	25
61	8.27	0.75	616	453	400	150	35	13.25
90	7.62	1.9	1589	1110	490	200	490	46.5
105	7.72	1.09	1948	585	300	150	6.6	43.25
101	7.59	1.44	2118	465	300	100	6.9	2.8
36	7.91	0.67	1068	753	180	150	0.5	48.5
42	7.92	0.73	1797	934	180	160	1.8	34.75
73	8.15	5	363	197	150	25	0.1	1.75
84	8.33	5.98	1733	201	150	15	0.6	1.2
134	7.96	6.91	19	167	170	15	1.7	1.25
Mean	**7.90**	**2.24**	**1123**	**538**	**288**	**117**	**63**	**23**
SD	**0.25**	**2.31**	**736**	**293**	**131**	**63**	**144**	**22**
Max	**8.33**	**6.91**	**2118**	**1110**	**530**	**200**	**490**	**54**

Min	7.58	0.62	19.00	167.00	150.00	15.00	0.10	0.74

VI.b2 - Chemical Characteristics (Macro Elements) of Sampled Domestic Wastewater along The Upper Litani Basin

Reference	pH	DO mg/l	BOD	Salinity mg/L	Magnesium mg/L as Mg++	Sodium mg/L as Na+	Iron mg/L as Fe
29	7.85	0.67	50	671	73	71	ND
38	7.95	1.1	1215	453	49	75	0.05
57	7.58	0.62	964	469	73	59	ND
61	8.27	0.75	616	453	49	47	0.23
90	7.62	1.9	1589	1110	121	119	ND
105	7.72	1.09	1948	585	121	36.3	0.01
101	7.59	1.44	2118	465	121	78	0.04
36	7.91	0.67	1068	753	12	55	0.08
42	7.92	0.73	1797	934	22	36.3	0.17
73	8.15	5	363	197	12	14	0.05
84	8.33	5.98	1733	201	36	8	0.1
134	7.96	6.91	19	167	7	5.8	0.02
Mean	**7.90**	**2.24**	**1123**	**538**	**58**	**50**	**0.08**
SD	**0.25**	**2.31**	**736**	**293**	**44**	**33**	**0.07**
Max	**8.33**	**6.91**	**2118**	**1110**	**121**	**119**	**0.23**
Min	**7.58**	**0.62**	**19.00**	**167.00**	**7.00**	**5.80**	**0.01**

VI.c1 - Chemical Characteristics (Trace Metals) of Sampled Domestic Wastewater along The Upper Litani Basin

Reference	Lead µg/L as Pb	Cadmium µg/L as Cd	Chromium µg/L as Cr	Nickel µg/L as Ni	Copper µg/L as Cu	Zinc µg/L as Zn
29	*	*	*	*	*	*
38	*	*	*	*	*	*
57	*	*	*	*	*	*
61	*	*	*	*	*	*
90	*	*	*	*	*	*
105	ND	2.197	1.12	57.011	8.414	49.2964
101	*	*	*	*	*	*
36	*	*	*	*	*	*
42	ND	3.338	5.05	9.245	0.414	5.3681
73	*	*	*	*	*	*
84	*	*	*	*	*	*
134	ND	4.973	0.64	0.127	0.551	22.0206
Mean		**3.50**	**2.27**	**22.13**	**3.13**	**26**
SD		**1.40**	**2.42**	**30.55**	**4.58**	**22**

Max		**4.97**	**5.05**	**57.01**	**8.41**	**49**
Min		**2.20**	**0.64**	**0.13**	**0.41**	**5**

*: 20% of the samples were tested

VI.c2 - Chemical Characteristics (Trace Metals) of Sampled Domestic Wastewater along The Upper Litani Basin

Reference	Aluminum µg/L as Al	Barium µg/L as Ba	Cobalt µg/L as Co	Boron µg/L as B	Manganese mg/L as Mn	Molybdenum µg/L as Mo	Mercury µg/L as Hg	Arsenic µg/L as As
29	*	*	*	*	0.05	*	*	*
38	*	*	*	*	0.061	*	*	*
57	*	*	*	*	0.074	*	*	*
61	*	*	*	*	0.083	*	*	*
90	*	*	*	*	0.115	*	*	*
105	54.3	289.8	0.26	ND	0.085	2.21	ND	ND
101	*	*	*	*	0.064	*	*	*
36	*	*	*	*	0.117	*	*	*
42	44.5	282.6	0.4	ND	0.031	1.63	ND	ND
73	*	*	*	*	0.056	*	*	*
84	*	*	*	*	0.04	*	*	*
134	27	380.9	0.3	ND	0.049	1.63	ND	ND
Mean	**42**	**318**	**0.32**		**0.07**	**1.82**		
SD	**14**	**55**	**0.07**		**0.03**	**0.33**		
Max	**54**	**381**	**0.40**		**0.12**	**2.21**		
Min	**27**	**283**	**0.26**		**0.03**	**1.63**		

*: 20% of the samples were tested

VI.d - Microbiological Characteristics of Sampled Domestic Wastewater along The Upper Litani Basin

Reference	Total Coliforms/ 100ml	Fecal coliforms/ 100 ml	Strep Fecalis/ 100ml
29	0	0	0
38	0	0	0
57	TNTC	120	0
61	TNTC	3	0
90	TNTC	TNTC	TNTC
105	20	0	0
101	0	0	0
36	0	0	0
42	0	0	0
73	TNTC	70	0
84	TNTC	32	0

134	TNTC	TNTC	0

8.7. INDUSTRIAL RESULTS

VII.a - Physical Characteristics of Sampled Industrial Wastewater along The Upper Litani Basin

Reference	T °C	CND µs/cm	TDS mg/l
54	18.3	396	275
91		1029	715
136		1116	779
71		1068	750
171		502	350
172		3100	2160
174		5360	3710
Mean	**18.30**	**1796**	**1248**
SD		**1808**	**1252**
Max	**18.30**	**5360**	**3710**
Min	**18.30**	**396**	**275**
EPA standards			**500**
WHO guidelines			**1000**

VII.b1- Chemical Characteristics (Macro Elements) of Sampled Industrial Wastewater along The Upper Litani Basin

Reference	pH	DO mg/l	BOD	Salinity mg/L	AlK mg/l as CaCO3	Chlorides mg/l Cl-	NO3-N mg/l	NH3-N mg/l
54	8.23	5.48	34	196	230	50	0.5	0.35
91	7.35	1.61	2138	509	230	250	1.1	2.3
136	7.36	5.6		555	230	30	2.5	1.03
71	4.54	4.13	1710	535	220	150	UR	19.6
171	7.06	0.16	934	249	114	65	0.1	1.04
172	4.96	0.32	3550	1510	96	305	5.5	4.1
174	6.72	0.25	2240	2630	1600	400	4	7.8
Mean	**6.60**	**2.51**	**1768**	**883**	**389**	**179**	**2.28**	**5.17**
SD	**1.35**	**2.49**	**1203**	**884**	**537**	**143**	**2.13**	**6.86**
Max	**8.23**	**5.60**	**3550**	**2630**	**1600**	**400**	**5.50**	**19.60**
Min	**4.54**	**0.16**	**34**	**196**	**96**	**30**	**0.10**	**0.35**
EPA standards	**6.5-8.5**					**250**	**10**	
EPA secondary standards								
WHO guidelines	**6.8-8**					**250**	**10**	

VII.b2 - Chemical Characteristics (Macro Elements) of Sampled Industrial Wastewater along The Upper Litani Basin

Reference	Orthophosphates mg/l PO4	Sulfates mg/l SO4--	Potassium mg/L as K+	Calcium mg/L as Ca++	Magnesium mg/L as Mg++	Sodium mg/L as Na+	COD mg/L	Iron mg/L as Fe
54	4.1	23	1.18	48	44	15	165	0.02
91	0.18	190	12.36	176	44	62	452	0.15
136	0.04	40	4.2	160	24	31.1	73	0.05
71	0.11	52	5.94	144	131	84	127	1.67
171	1.45	2	3.07	108	27	39	282	0.05
172	2.22	24	214	168	22	51	680	ND
174	24	UR	58.7	176	24	204	31.6	0.24
Mean	**4.59**	**55**	**43**	**140**	**45**	**69**	**259**	**0.36**
SD	**8.69**	**68**	**78**	**47**	**39**	**63**	**234**	**0.65**
Max	**24.00**	**190**	**214**	**176**	**131**	**204**	**680**	**1.67**
Min	**0.04**	**2**	**1**	**48**	**22**	**15**	**32**	**0.02**
EPA standards								
EPA secondary standards								**0.3**
WHO guidelines								

VII.c1 - Chemical Characteristics (Trace Elements)of Sampled Industrial Wastewater along The Upper Litani Basin

Reference	Lead µg/L as Pb	Cadmium µg/L as Cd	Chromium µg/L as Cr	Nickel µg/L as Ni	Copper µg/L as Cu	Zinc µg/L as Zn	Aluminum µg/L as Al
54	*	*	ND	*	1.985	18.42	*
91	*	*	5	*	0.973	16.29	*
136	ND	2.901	0.2	2.271	1.345	18.62	22.6
71	*	*	11.6	*	3.358	47.32	*
171	ND	0.54	ND	0.93	1.725	43.93	22.11
172	ND	0.93	4.1	1.03	2.245	29.19	25.14
174	ND	1.21	3.61	1.21	2.403	47.21	18.92

Mean		**1.40**	**4.90**	**1.36**	**2.00**	**32**	**22**
SD		**1.04**	**4.16**	**0.62**	**0.78**	**14**	**3**
Max		**2.90**	**11.60**	**2.27**	**3.36**	**47**	**25**
Min		**0.54**	**0.20**	**0.93**	**0.97**	**16**	**19**
EPA standards		**0.005**	**0.1**				
EPA Secondary standards					**1**	**5**	**0.005-0.2**
WHO	**0.01**	**0.003**	**0.05**	**0.07**	**2**		**0.2**

* 20% 0f the samples were tested

VII.c2 - Chemical Characteristics (Trace Elements)of Sampled Industrial Wastewater along The Upper Litani Basin

Reference	**Barium µg/L as Ba**	**Cobalt µg/L as Co**	**Boron µg/L as B**	**Manganese mg/L as Mn**	**Molybdenum µg/L as Mo**	**Mercury µg/L as Hg**	**Arsenic µg/L as As**
54	1012	0.27	*	0.07	2.08	*	*
91	1034	0.18	*	0.203	2.52	*	*
136	288.9	4.16	ND	0.098	2.45	ND	ND
71	1054	0.11	*	0.035	2.31	*	*
171	998	0.14	ND	0.035	2.14	ND	ND
172	1022	0.14	ND	ND	2	ND	ND
174	1009	0.22	ND	ND	2.48	ND	ND
Mean	**917**	**0.75**		**0.09**	**2.28**		
SD	**278**	**1.51**		**0.07**	**0.21**		
Max	**1054**	**4.16**		**0.20**	**2.52**		
Min	**289**	**0.11**		**0.04**	**2.00**		
EPA standards	**2**					**0.002**	**0.01**
EPA Secondary standards				**0.05**			
WHO	**0.7**		**0.5**	**0.4**	**0.07**	**0.006**	**0.01**

* 20% 0f the samples were tested

VII.d - Microbiological Characteristics of Sampled Industrial Wastewater along The Upper Litani Basin

Reference	Total Coliforms/ 100ml	Fecal coliforms/ 100 ml	Strep Fecalis/ 100ml
54	0	0	0
91	0	0	0
136	TNTC	TNTC	0
71	TNTC	75	0
171	0	0	0
172	0	0	0
174	0	0	0

8.8. SOIL RESULTS

VIII.a1 Characteristics of Soil Samples along the upper Litani Basin

Reference	Code	%TC	%OC	pH	Mo	Pb	As	Hg	Zn	Cu
22	001-YUSSOL-SAD	8.7	3.1	8.1	0	0	27	5	90	45
25	002-YUSSOL-HEZ	43.1	27.9	7.3	0	6	14	6	65	40
33	003-YUSSOL-FRZ	54.9	32	7.8	0	33	11	0	252	147
36	004-YUSSOL-FRZ	41.4	13.8	8	0	0	19	9	73	46
40	005-YUSSOL-RYK	53.3	17.9	7.9	0	68	17	7	67	32
41	006-YUSSOL-RYK	26.4	4.8	7.8	0	0	28	7	104	50
58	019-OUSSOL-QRM	79.0	26.6	8.1	0	16	11	0	63	30
61	020-OUSSOL-ZHL	56.1	34.2	7.4	0	8	10	0	84	33
68	021-OUSSOL-JDT	28.6	15.7	7.8	0	0	26	6.3	77	47
71	022-OUSSOL-CHL	33.7	20.2	7.7	0	0	20	6	49	38
73	023-OUSSOL-MRT	32.7	23.9	8.8	0	164	25	7	299	58
75	024-OUSSOL-HRJ	51.4	14.5	7.9	0	21	13	5.7	61	40
76	025-OUSSOL-TNL	35.5	33.1	8.3	0	0	19	8	69	33
83	026-OUSSOL-ANJ	77.0	41.8	8.7	0	8	6	0	33	23
89	027-GUSSOL-KBL	41.1	8.2	7.5	0	0	18.2	0	197	82
90	028-GUSSOL-AMK	44.4	7.5	7.8	0	0	19.11	7.8	78	52
92	029-GUSSOL-AMK	7.5	0.95	8.1	0	0	22	0	137	44
95	030-GUSSOL-MAN	53.1	22.6	8.6	0	0	12.4	0	69	29
104	031-GUSSOL-LUC	6.1	0.98	8.5	0	0	20	0	68	52
105	032-GUSSOL-GHZ	37.8	11.4	8.5	0	6.3	15	7.9	85	43
108	033-GUSSOL-JBJ	34.5	7.9	8.4	0	0	18.4	0	66	46
111	034-GUSSOL-JBJ	43.6	12.4	7.9	0	0	20	7	52	40
133	035-YUSSOL-HSD	41.3	28	7.7	0	6	16	7	70	41
25	036-YUSSOL-HEZ	46.2	14.7	7.9	0	0	15	0	70	35
	Mean	**41**	**18**	**8**	**0**	**14**	**18**	**4**	**95**	**47**
	SD	**18**	**11**	**0**	**0**	**35**	**6**	**4**	**65**	**24**

	Max	**79**	**42**	**9**	**0**	**164**	**28**	**9**	**299**	**147**
	Min	**6**	**1**	**7**	**0**	**0**	**6**	**0**	**33**	**23**

VIII.a2 Characteristics of Soil Samples along the upper Litani Basin

Reference	Code	Ni	Co	Fe	Mn	Cr	Ca	K	S
22	001-YUSSOL-SAD	136	0	54151	1226	180	32011	14519	9
25	002-YUSSOL-HEZ	77	0	25348	569	110	178222	8500	9
33	003-YUSSOL-FRZ	113	0	17815	354	112	236722	9236	17
36	004-YUSSOL-FRZ	136	0	34915	615	190	175616	9081	10
40	005-YUSSOL-RYK	91	0	20599	406	100	235809	7034	40
41	006-YUSSOL-RYK	140	0	56404	876	210	110275	8171	15
58	019-OUSSOL-QRM	82	0	13498	213	50	313479	6136	11
61	020-OUSSOL-ZHL	58	0	18251	280	90	219223	6863	14
68	021-OUSSOL-JDT	91	0	46650	613	160	111000	9928	16
71	022-OUSSOL-CHL	95	0	44871	688	201	134810	8931	12
73	023-OUSSOL-MRT	97	0	42661	555	180	126698	8450	20
75	024-OUSSOL-HRJ	100	0	25355	354	90	215271	5999	10
76	025-OUSSOL-TNL	114	0	40351	681	200	146654	8917	12
83	026-OUSSOL-ANJ	77	0	6957	123	35	377430	3333	26
89	027-GUSSOL-KBL	131	0	34043	573	220	171681	7717	39
90	028-GUSSOL-AMK	104	0	41785	591	150	190576	8986	15
92	029-GUSSOL-AMK	108	0	50417	977	140	25893	11122	50
95	030-GUSSOL-MAN	48	0	22842	462	85	220208	4184	9
104	031-GUSSOL-LUC	101	0	42358	1217	160	21074	9792	6
105	032-GUSSOL-GHZ	90	0	28631	607	272	152218	8378	14
108	033-GUSSOL-JBJ	87	0	34224	689	150	137931	8747	7
111	034-GUSSOL-JBJ	85	0	35771	456	100	179750	8225	14
133	035-YUSSOL-HSD	101	0	25441	570	125	168384	9612	20
25	036-YUSSOL-HEZ	91	0	23993	545	120	200686	6868	9
	Mean	**98**	**0**	**32805**	**593**	**143**	**170068**	**8280**	**17**
	SD	**23**	**0**	**13169**	**272**	**57**	**82090**	**2225**	**11**
	Max	**140**	**0**	**56404**	**1226**	**272**	**377430**	**14519**	**50**
	Min	**48**	**0**	**6957**	**123**	**35**	**21074**	**3333**	**6**

VIII.a' Characteristics of Soil Samples along the upper Litani Basin

Reference	Code	Ba	Cd	Al	P	Cl	Mg
22	001-YUSSOL-SAD	206	0	40829	90	1527	33272
25	002-YUSSOL-HEZ	297	0	22027	54	1116	40484
33	003-YUSSOL-FRZ	135	0	16888	75	998	45736
36	004-YUSSOL-FRZ	358	15	23789	61	1096	40592
40	005-YUSSOL-RYK	203	0	16876	100	1225	45360
41	006-YUSSOL-RYK	105	0	39553	80	1181	38519
58	019-OUSSOL-QRM	251	13	5224	40	738	50463
61	020-OUSSOL-ZHL	203	12	8742	60	894	41903
68	021-OUSSOL-JDT	0	0	25592	89	1228	38622
71	022-OUSSOL-CHL	199	0	24397	70	1140	39057
73	023-OUSSOL-MRT	231	0	28812	0	1429	36738
75	024-OUSSOL-HRJ	267	0	14334	52	946	44281
76	025-OUSSOL-TNL	258	9	25766	70	1683	39974
83	026-OUSSOL-ANJ	231	10	0	34	440	55835
89	027-GUSSOL-KBL	0.00	0.00	25257	81	1401	43256
90	028-GUSSOL-AMK	188	0	22987	61	1261	44135
92	029-GUSSOL-AMK	87	0	39172	84	1472	419
95	030-GUSSOL-MAN	0	0	10402	46	916	44231
104	031-GUSSOL-LUC	252	0	33128	70	1322	3123
105	032-GUSSOL-GHZ	259	8.9	21368	64	1077	38276
108	033-GUSSOL-JBJ	280	0	22636	67	1173	37616
111	034-GUSSOL-JBJ	347	0	17360	55	1036	42948
133	035-YUSSOL-HSD	203	0	22862	62	2739	40658
25	036-YUSSOL-HEZ	282	0	23297	5509	1033	43963

	Ba	Cd	Al	P	Cl	Mg
Mean	**202**	**2.83**	**22137**	**291**	**1211**	**38728**
SD	**101**	**5.13**	**10186**	**1112**	**420**	**12287**
Max	**358**	**15.00**	**40829**	**5509**	**2739**	**55835**
Min	**0.00**	**0.00**	**0.00**	**0.00**	**440.00**	**419.00**

VIII.b1 Characteristics of Soil Samples along the Canal 900

Reference	Code	%TC	%OC	pH	Mo	Pb	As	Hg
44	007-WCLSOL-JBJ	30.02	16.3	8.3	0	0	22	0
53	008-WCLSOL-KDL	11.43	1.1	84	0	0	23	0
45	009-ECLSOL-JBJ	23.82	9.7	8.1	0	0	26	6
46	010-WCLSOL-TW2	14.99	5.4	7.9	0	0	25	0
47	011-WCLSOL-BAA	4.76	0.97	8.2	0	0	23	0
47	012-ECLSOL-BAA	6.27	1.39	7.8	0	0	25	0
48	013-ECLSOL-TW1	57.67	28.9	7.7	0	0	14	0
49	014-ECLSOL-QRN	55.70	22.8	8.8	0	6	12	9
49	015-WCLSOL-QRN	59.03	19.8	7.5	0	13	9	0
50	016-WCLSOL-QRN	21.67	12.6	7.9	0	0	22	7
52	017-WCLSOL-TW3	53.03	34.3	8	0	0	15	9
28	018-ECLSOL-KML	40.58	32.4	8.1	0	0	15	6

Mean	**32**	**15**	**14**	**0.00**	**1.58**	**19.25**	**3.08**
SD	**21**	**12**	**22**	**0.00**	**3.99**	**5.85**	**3.92**
Max	**59**	**34**	**84**	**0.00**	**13.00**	**26.00**	**9.00**
Min	**4.76**	**0.97**	**7.50**	**0.00**	**0.00**	**9.00**	**0.00**

VIII.b2 Characteristics of Soil Samples along the Canal 900

Reference	Code	Zn	Cu	Ni	Co	Fe	Mn	Cr	Ca
44	007-WCLSOL-JBJ	158	64	189	0	42673	643	230	108871
53	008-WCLSOL-KDL	123	60	101	0	55917	1077	325	44653
45	009-ECLSOL-JBJ	177	73	237	0	52034	791	250	85195
46	010-WCLSOL-TW2	177	72	224	0	54486	936	270	52433
47	011-WCLSOL-BAA	88	50	111	0	48950	1133	150	17262
47	012-ECLSOL-BAA	97	44	120	0	49188	818	210	22345
48	013-ECLSOL-TW1	165	51	134	0	19489	335	150	256693
49	014-ECLSOL-QRN	151	55	119	0	18457	307	160	258906
49	015-WCLSOL-QRN	151	60	144	0	14567	317	120	280467
50	016-WCLSOL-QRN	197	63	247	0	46963	790	350	80722
52	017-WCLSOL-TW3	93	46	152	0	25025	480	120	228362
28	018-ECLSOL-KML	60	36	98	0	29317	573	100	170378

	Mean	**136**	**56**	**156**	**0**	**38089**	**683**	**203**	**133857**
	SD	**43**	**11**	**54**	**0**	**15534**	**288**	**83**	**99507**
	Max	**197**	**73**	**247**	**0**	**55917**	**1133**	**350**	**280467**
	Min	**60.00**	**36.00**	**98.00**	**0.00**	**14567.00**	**307.00**	**100.00**	**17262.00**

VIII.b' Characteristics of Soil Samples along the Canal 900

Reference	Code	K	S	Ba	Cd	Al	P	Cl	Mg
44	007-WCLSOL-JBJ	8206	9	284	0	28195	72	1006	37169
53	008-WCLSOL-KDL	12402	12	43	0	41742	80	1548	32148
45	009-ECLSOL-JBJ	8407	10	281	14	32073	70	1324	34413
46	010-WCLSOL-TW2	8217	9	204	0	36420	76	1419	32338
47	011-WCLSOL-BAA	8198	9	195	0	39700	68	1471	29613
47	012-ECLSOL-BAA	7301	7	203	0	36580	66	1391	30204
48	013-ECLSOL-TW1	6643	8	70	0	14876	66	868	46890
49	014-ECLSOL-QRN	7521	17	90	0	17912	94	935	46554
49	015-WCLSOL-QRN	5887	13	266	13	11823	77	867	48211
50	016-WCLSOL-QRN	8819	16	315	12	36989	126	1334	34974
52	017-WCLSOL-TW3	6389	9	303	0	22032	52	834	42458
28	018-ECLSOL-KML	5543	8	248	0	23518	60	1073	38548

Mean	**7794**	**10.58**	**209**	**3.25**	**28488**	**76**	**1173**	**37793**
SD	**1796**	**3.23**	**94**	**5.89**	**10252**	**19**	**267**	**6717**
Max	**12402**	**17.00**	**315**	**14.00**	**41742**	**126**	**1548**	**48211**
Min	**5543**	**7.00**	**43**	**0.00**	**11823**	**52**	**834**	**29613**

8.9. RIVER SEDIMENT RESULTS

IX.a Characteristics of Sediment Samples of the Litani River and Tributaries

code	Reference	%TC	%TOC	pH	Mo	Pb	As	Hg	Zn	Cu	Ni	Co	Fe	Mn
S1	**36**	53.15	3.4	8.3	0	41	13	n	456	114	78	0	25757	268
S2	**58**	50.03	2.9	7.9	0	0	12	0	55	35	36	0	16489	163
S3	**74**	51.48	6.5	8.1	0	9	7	6	50	25	40	0	16167	167
S4	**108**	48.24	0.87	8.4	0	0	14	0	62	40	71	0	25943	421

Mean	50.72	3.42	8.18	0.00	13	11.50	2.00	156	54	56	0	21089	255
SD	2.09	2.33	0.22	0.00	19	3.11	3.46	200	41	21	0	5500	121
Max	53.15	6.50	8.40	0.00	41	14.00	6.00	456	114	78	0	25943	421
Min	48.24	0.87	7.90	0.00	0	7.00	0.00	50	25	36	0	16167	163

IX.a' Characteristics of Sediment Samples of the Litani River and Tributaries

code	Reference	Cr	Ca	K	S	Ba	Cd	Al	P	Cl	Mg
S1	**36**	100	221666	6920	84	nd	0	13309	95	1271	47916

S2	**58**	50	192744	5364	22	162	0	7012	56	849	39406
S3	**74**	45	215633	3407	20	0	0	7601	47	787	41953
S4	**108**	110	200284	6570	13	284	11	14747	58	1045	42222
	Mean	76	207582	5565	34.75	149	2.75	10667	64.00	988	42874
	SD	34	13374	1586	33.06	142	5.50	3932	21.21	218	3593
	Max	110	221666	6920	84.00	284	11.00	14747	95.00	1271	47916
	Min	45	192744	3407	13.00	0	0.00	7012	47.00	787	39406

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