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# CHEMICAL AND MICROBIOLOGICAL ANALYSIS OF WELLSAND RIVERS IN LEBANESE URBAN CITIES


## Abstract

Unsafe drinking water has been implicated in numerous health problems in developing countries. This latter is a result of the increase in human population and urbanization. However, there is a lack of knowledge about the water contamination in the Lebanese urban cities. Consequently, it has become necessary to monitor the chemical and microbiological parameters of different wells and rivers in Lebanese Urban Cities. In this present study, we analyzed the chemical and microbiological characteristics of water coming from different wells in Urban Cities (Baakline, Hasbaya, Kfarchakhna, Kesrwan, Antelias, Fanar, Lebaa, Tal Amara, Tyre) and seven Lebanese rivers (Hasbani, Rachiine, Kadisha, Awali, Ghzayel, Berdawni, Litani). Heavy metals (Mn, Pb, Cu, Fe, Zn, Cd, Ar, Hg), various chemical elements (Ca, Mg, Bicarbonate, Na, K, Nitrate and sulfur) and different microbial strains were determined for each source. The samples collected from the wells of the different cities were not conform (20 to 82%) in heavy metals, not conform (20 to 85%) in chemical elements as well as not conform (52 to 100%) in the microbial load to the Lebanese standard of water (LIBNOR). The chemical and microbiological characteristics of all river samples were not conform to the Lebanese standard of the water, with some samples even contaminated with mercury. Noting that many cases of bacterial infections were detected in some cities due to the bacterial contamination of the wells, a need of ensuring a reliable access of a safe drinking water is important to sustain our Lebanese cities.



## Keywords

Contaminants, Wells, Rivers, Lebanese Urban Cities.

# CHEMICAL AND MICROBIOLOGICAL ANALYSIS OF WELLS AND RIVERS IN LEBANESE URBAN CITIES

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**ABSTRACT:** *Unsafe drinking water has been implicated in numerous health problems in developing countries. This latter is a result of the increase in human population and urbanization. However, there is a lack of knowledge about the water contamination in the Lebanese urban cities. Consequently, it has become necessary to monitor the chemical and microbiological parameters of different wells and rivers in Lebanese Urban Cities. In this present study, we analyzed the chemical and microbiological characteristics of water coming from different wells in Urban Cities (Baakline, Hasbaya, Kfarchakhna, Kesrwan, Antelias, Fanar, Lebaa, Tal Amara, Tyre) and seven Lebanese rivers (Hasbani, Rachiine, Kadisha, Awali, Ghzayel, Berdawni, Litani). Heavy metals (Mn, Pb, Cu, Fe, Zn, Cd, Ar, Hg), various chemical elements (Ca, Mg, Bicarbonate, Na, K, Nitrate and sulfur) and different microbial strains were determined for each source. The samples collected from the wells of the different cities were not conform (20 to 82%) in heavy metals, not conform (20 to 85%) in chemical elements as well as not conform (52 to 100%) in the microbial load to the Lebanese standard of water (LIBNOR). The chemical and microbiological characteristics of all river samples were not conform to the Lebanese standard of the water, with some samples even contaminated with mercury. Noting that many cases of bacterial infections were detected in some cities due to the bacterial contamination of the wells, a need of ensuring a reliable access of a safe drinking water is important to sustain our Lebanese cities.*

**KEYWORDS:** *Contaminants, Wells, Rivers, Lebanese Urban Cities.*

## 1. INTRODUCTION

Water is a crucial element for the survival of all living organisms. Safe water is essential for human health and well-being as well as sustainable development (Massoud et al. 2010). Many diseases in developing countries are caused by contaminated water (Yoshida, Yamauchi, and Fan Sun 2004), considered to be among the leading causes of death in children, elderly and people with compromised immune system. Failure to provide safe water might expose the community to risk of outbreaks as well as waterborne diseases (Massoud et al. 2010).

In Lebanon, the aquatic environment is polluted in many parts of the country leading to many water-borne diseases (Harakeh et al. 2006). Water can be contaminated chemically, physically or microbiologically. Heavy metal pollution is one of the most serious environmental issues globally (Mohiuddin et al. 2010). Heavy metals like chromium, lead, cadmium, and arsenic were found to exhibit extreme toxicity even at trace levels (Mohiuddin et al. 2011). In USA, research has shown that contaminated water with lead has increased the exposure to higher incidence of miscarriages and fetal death (Edwards 2014) .

Bacteriological contamination of the water could result in many chronic and acute infectious diseases like food poisoning, intestinal diarrhea, cholera, typhoid fever, dysentery and others (Ashbolt 2004). Thus good drinking water is a luxury but one of the most essential requirements of life.

In Lebanon, the rivers in the urban cities are subjected to pollution from different point sources (Jurdi et al. 2001). Litani River was well studied by different researchers, who showed that this river is highly vulnerable to contamination, thus impacting socioeconomic development and community resilience in the basin (Assaf and Saadeh 2007). Several studies have shown considerable levels of chemical and biological contamination across different points of the river. Moderated contamination level of Nitrate in most of the assessed wells rendering them unsuitable for drinking (Ramadan, Beighley, and Ramamurthy 2013). Rivers are also know to be a dominant pathway for metals transport (Harikumar, Nasir, and Mujeebu Rahman 2009). This contamination could be due to a lack of well-planned urbanization, inadequate wastewater and solid-waste services, as well as the overuse of agrochemicals .

In Lebanon, studies that evaluate the chemical and biological contamination levels of river's and well's water are few. Therefore, the aim of this study was to provide an overview of the occurrence of heavy metals (Mn, Pb, Cu, Fe, Zn, Cd, Ar, Hg), various chemical elements (Ca, Mg, Bicarbonate, Na, K, Nitrate and sulfur) and different microbial strains water coming from different wells in Urban Cities (Baakline, Hasbaya, Kfarchakhna, Kesrwan, Antelias, Fanar, Lebaa, Tal Amara, Tyre) and seven Lebanese rivers (Hasbani, Rachiine, Kadisha, Awali, Ghzayel, Berdawni, Litani) The identification of the chemical and biological contaminants in the water samples coming from the wells and rivers in different Lebanese Urban cities is essential to develop an effective water usage strategy resulting in an effective pollution remediation.

## 2. MATERIALS AND METHODS

### 2.2 Sampling

Water samples were collected from different sources such as wells, spring, rivers and drinking water were subjected respectively to bacteriological, chemical elements and heavy metals screening. Ten samples were collected from every point at each time.

The river water samples were taken at a depth of 50 cm, according to the AFNOR norm NF T90-100. For the other samples, coming from wells, springs, or drinking water, the tap was opened for 10 min then burned with alcohol for sterilization purpose. Afterwards, the tap was reopened for 15 min before taking samples. The bottles containing the water samples were placed in coolers at 4 ° C and transported to the laboratory within 24 hours. After arriving at the laboratory, the samples were immediately filtered through 0.45 μm pore cellulose filters by vacuum suction into Pyrex flasks that had been previously washed in 10% v/v nitric acid. The water samples were transferred into sterile glass bottle and stored at 4 °C prior to analysis.

### 2.3 Standards

Standard solutions of the heavy metals, namely, lead (Pb), cadmium (Cd), and copper (Cu), cobalt (Co), nickel (Ni), and zinc (Zn), were purchased from Merck (Darmstadt, Germany). The standards were prepared from the individual 1000 mg/L standards (Merck) supplied in 0.1 M HNO3. A series of working standards were prepared from these standard stock solutions.

### 2.4 Heavy metals Analysis

Heavy metals like manganese (Mn), lead (Pb), copper (Cu), Iron (Fe), Zinc (Zn), Cadmium (Cd), Arsenic (Ar), Mercury (Hg) in water samples were analyzed using furnace atomic absorption spectrometry on three replicates.

### 2.5 Chemical analysis

The methods used for the determination of the following chemical elements in water (Ca, Mg, Bicarbonate, Na, K, Nitrate and sulfur) is presented in the following table:

Table 1. Methods of analysis of the different chemical elements

| Parameter | Units | Methods | Norms |
|---|---|---|---|
| **Calcium ($ca^{2+}$)** | mg/L | Titrated by EDTA 0.01M | ISO 6058-1984 |
| **Magnesium ($Mg^{2+}$)** | mg/L | Flame Photometer | NFT90-019 |
| **Sodium (Na)** | mg/L | Flame Photometer | NFT90-019 |
| **Potassium (k)** | mg/L | Flame Photometer | NFT90-019 |

| | | | |
|---|---|---|---|
| **Nitrates ($NO_3^-$)** | mg/L | Spectrophotometer _ Biomate 5 | ISO 7890-3:1988 |
| **Sulfates ($SO_4^{2-}$)** | mg/L | Spectrophotometer _ Biomate 5 | NFT90-040 |

### 2.6 Bacteriological Analysis

Bacteriological assessments were carried out using Total Aerobic Plate Count on a Plate Count Agar (PCA), according to the ISO 6222:1999. All the media were prepared according to the Manufacturer's specification. Total coliform counts were carried out by the standard plate count technique using Endo agar (ISO 9308-1 :2000). Faecal coliform was determined using Eosin methylene blue medium via pour plate technique (ISO 9308-1 :2000). Streptococci was determined using Bile Esculine Azide Agar (ISO 7899-2 :1984). Pseudomonas aeruginosa was determined using Cetrimide (ISO 16266 :2006).

## 3 RESULTS AND DISCUSSION

### 3.2 Bacteriological quality of the rivers in Lebanese Urban Cities

The bacteriological analysis of seven rivers (*Hasbani*, *Rachiine*, *Kadisha*, *Awali*, *Ghzayel*, *Berdawni*, *Litani*) in the Lebanese Urban cities is shown in Table 2. Most of the values largely exceed the limits of the Lebanese norms of water quality, except for *Pseudomonas aeruginosa*, which was conform to the norm in all the samples.

The total coliform counts were highest in Berdawni river sample with a value of 6 x $10^6$ CFU/ml while the least counts of 5796 CFU/ml were recorded in Hasbani water. Similar results were obtained for Fecal coliforms and *Escherichia coli*.

The bacteriological values for total aerobic count, coliform counts, fecal coliforms as well as *Escherichia coli* and *Streptococcus* group D did not meet the LIBNOR standard for water quality. The presence of coliforms indicates contamination with wastewater, which further aggravates health conditions (Semerjian 2011).

According to the European Economic Community, the levels of fecal coliforms in bathing waters should not exceed 100 FC/100 ml (Servais et al. 2007).Various health outcomes such as gastrointestinal infections have been associated with fecally polluted water, resulting in a significant burden of disease (WHO et al. 2011).

These results are indicative of the presence of pathogens that may cause water-borne diseases arising from wastewater contamination. This could be due to the urban wastewater discharge in the rivers and improper urban activities. Consequently, the river quality samples located in the different Lebanese Urban cities are classified as not be suitable for irrigation usage, based on the comparison of this water with the Seq-eaux standard of irrigation water. Noting that this water is being used for irrigation in Lebanon.

Table 2. Bacteriological data of water samples taken from 7 Lebanese rivers. For each river, ten samples were taken. The average was shown in the table.
*refers to the Lebanese standard of water LIBNOR 161:1999

| **z** | **Total aerobic count 22°C (CFU/mL)** | **Total aerobic count 37°C (CFU/mL)** | **Total Coliforms (CFU/100mL)** | **Fecal Coliforms (CFU/250mL)** | ***Escherichia coli* (CFU/250mL)** | ***Streptococcus group D* (CFU/250mL)** | ***Pseudomonas aeruginosa* (CFU/250mL)** |
|---|---|---|---|---|---|---|---|
| | **100*** | **20*** | **<1*** | **<1*** | **<1*** | **<1*** | **<1*** |
| **Hasbani** | **1830.00** | **1200.00** | **5796.00** | **192.00** | **11.00** | <1 | <1 |
| **Rachiine** | **3.00E+07** | **2.30E+07** | **1.10E+05** | **1.88E+04** | **1.25E+04** | **2125** | <1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Kadisha** | **1.00E+06** | **2.00E+06** | **2.00E+04** | **2.50E+03** | **1.11E+03** | **250** | <1 |
| **Awali** | **1.00E+03** | **2.00E+03** | **3.90E+03** | **2.14E+02** | **1.80E+02** | **2.20E+02** | <1 |
| **Ghzayel** | **1.00E+05** | **1.20E+06** | **3.60E+05** | **1.75E+04** | **5.63E+03** | **1.06E+04** | <1 |
| **Berdawni** | **1.00E+06** | **3.50E+07** | **6.00E+06** | **3.38E+04** | **7.50E+03** | **2.31E+04** | <1 |
| **Litani** | **1.00E+08** | **3.00E+06** | **2.00E+05** | **1.25E+04** | **6.25E+03** | **1.25E+04** | <1 |
| **Average load for the rivers** | **1.89E+07** | **9.17E+06** | **9.57E+05** | **1.22E+04** | **4.74E+03** | **8.14E+03** | **<1** |

### 3.3 Bacteriological quality of the wells in Lebanese Urban Cities

The bacteriological analysis of nine wells (*Baakline*, *Hasbaya*, *Kfarchakhna*, *Kesrwan*, *Antelias*, *Fanar*, *Lebaa*, *Tal Amara*, *Tyre*) in the Lebanese Urban cities is shown in Table 3. The values of Total aerobic count and total coliforms largely exceed the limits of the Lebanese norms of water quality for most of the samples taken from the different wells located in Lebanese Urban cities. The high level of contamination with total coliforms could be due to infiltration of wastewater into the wells, due to inadequate waste treatments strategies in Lebanon. Wastewater intrusions arise from the cross connection of sewer pipes with domestic pipes, consequently leading to coliforms contamination of the water. These results are in accordance with the study of Mcheik et al., 2017 who showed a degree of deterioration of private well sources by the sea and the wastewater infiltration in the domestic water profile of the region surrounding Al-Ghadir River at Kfarshima and Al-Sahra (Mcheik, Amale, Aida Ibrik, Rawane Mehdi 2017). Fecal coliforms and *Escherichia coli* exceeded the norms only in Tal Amara and Tyre. *Streptococcus group D* was not conform to the LIBNOR standard of water in *Antelias*, *Tal Amara* and *Tyre*. In concordance with the results of the river, presented in table 2, *Pseudomonas aeruginosa* was not found in all the wells samples.

Table 3. Bacteriological data of water samples taken from 9 Lebanese wells. For each well, ten samples were taken. The average was shown in the table.
*refers to the Lebanese standard of water LIBNOR 161:1999

| **Well** | **Total aerobic count 22°C (CFU/mL)** | **Total aerobic count 37°C (CFU/mL)** | **Total Coliforms (CFU/100mL)** | **Fecal Coliforms (CFU/250mL)** | ***Escherichia coli* (CFU/250mL)** | ***Streptococcus group D* (CFU/250mL)** | ***Pseudomonas aeruginosa* (CFU/250mL)** |
|---|---|---|---|---|---|---|---|
| | **100*** | **20*** | **<1*** | **<1*** | **<1*** | **<1*** | **<1*** |
| **Baakline** | **<10** | **<10** | **<1** | **<1** | **<1** | <1 | <1 |
| **Hasbaya** | **1.00E+03** | **4.00E+03** | **1.10E+03** | **<1** | **<1** | **<1** | <1 |
| **Kfarchakhna** | **1.00E+01** | **2.00E+01** | **2.20E+01** | **<1** | **<1** | **<1** | <1 |
| **Keserwan** | **1.00E+02** | **8.00E+01** | **<1** | **<1** | **<1** | **<1** | <1 |
| **Antelias** | **2.00E+03** | **1.00E+04** | **1.60E+03** | **<1** | **<1** | **1.15E+02** | <1 |
| **Fanar** | **1.00E+02** | **2.00E+01** | **4.10E+01** | **<1** | **<1** | **<1** | <1 |
| **Lebaa** | **1.00E+02** | **7.00E+01** | **5.00E+00** | **<1** | **<1** | **<1** | <1 |
| **Tal Amara** | **1.00E+03** | **1.00E+03** | **1.60E+03** | **1.84E+03** | **1.48E+03** | **1.05E+02** | <1 |
| **Tyre** | **2.00E+03** | **1.00E+03** | **8.80E+02** | **2.15E+02** | **1.95E+02** | **5.70E+01** | <1 |
| **Average load for the wells** | **7.89E+02** | **2.02E+03** | **7.50E+02** | **1.03E+03** | **8.35E+02** | **9.23E+01** | <1 |

### 3.4 Heavy metals presence in different wells and rivers water samples

The heavy metal concentration in the different water samples taken from the wells and the rivers is presented in Table 4. All the heavy metals were conform to the Lebanese norm of water LIBNOR 161:1999 in all the samples except the mercury. Mercury was exceeding the acceptable limit (0.001 mg/L) in all the water samples. Arsenic and cadmium were only excepting the acceptable level in Baakline well. Water pollution with mercury is one of the major problems confronting the health officials in many countries. This environmental and industrial pollutant might induce severe alterations in the tissues as well as many neurological abnormalities (Sener et al. 2007, Chuu, Liu, and Lin-Shiau 2007). This high level of mercury in water could be probably due to the crisis of municipal waste that occurred in Lebanon, resulted from the shortage in waste treatment. The water of the wells and river contaminated with mercury should not be used for agricultural use. Based on our results, it is highly recommended to monitor the level of heavy metals in water in order to employ the necessary environmental interventions.

Table 4. Heavy metals presence in the different water samples taken from the wells and the rivers.
*C refers to: conform to the Lebanese standard of water LIBNOR 161:1999
* NC refers to: not conform to the Lebanese standard of water LIBNOR 161:1999

| | Source | Manganese (Mn) | Lead (Pb) | Copper (Cu) | Iron (Fe) | Zinc (Zn) | Cadmium (Cd) | Arsenic (Ar) | Mercury (Hg) |
|---|---|---|---|---|---|---|---|---|---|
| | | 0.05 (mg/L) | 0.01 (mg/L) | 1 (mg/L) | 0.3 (mg/L) | 5 (mg/L) | 0.005 (mg/L) | 0.05 (mg/L) | 0.001 (mg/L) |
| Rivers | Hasbani | C* | C | C | C | C | C | C | NC* |
| | Rachiine | C | C | C | C | C | C | C | C |
| | Kadisha | C | C | C | C | C | C | C | C |
| | Awali | C | C | C | C | C | C | C | C |
| | Ghzayel | C | C | C | C | C | C | C | C |
| | Berdawni | C | C | C | C | C | C | C | C |
| | Litani | C | C | C | C | C | C | C | NC |
| Wells | Baakline | C | C | C | C | C | NC | NC | NC |
| | Hasbaya | C | C | C | C | C | C | C | NC |
| | Kfarchakhna | C | C | C | C | C | C | C | NC |
| | Keserwan | C | C | C | C | C | C | C | NC |
| | Antelias | C | C | C | C | C | C | C | NC |
| | Fanar | C | C | C | C | C | C | C | NC |
| | Lebaa | C | C | C | C | C | C | C | NC |
| | Tal Amara | C | C | C | C | C | C | C | NC |
| | Tyre | C | C | C | C | C | C | C | NC |

### 3.5 Chemical elements presence in different wells and rivers water samples

The chemical metal concentration in the different water samples taken from the wells and the rivers is presented in Table 5. Potassium, magnesium, sodium and sulfate are conform to the Lebanese norm. However, Calcium, bicarbonate and nitrate were found to be higher than the norm in some rivers and wells. Baakline well was found to be the most source of contamination for the heavy metals and chemical elements, although it’s bacterial load is very acceptable. The level of nitrate in the water should be controlled, since high levels of nitrate are associated with risks to human health, including thyroid gland, gastric cancer, as well as many health problems to pregnant women (Fadiran and Mamba 2005). The high level of nitrate could cause methemoglobinemia in infants (Fewtrell 2004)

Table 5. Chemical elements presence in the different water samples taken from the wells and the rivers.
*C refers to: conform to the Lebanese standard of water LIBNOR 161:1999
* NC refers to: not conform to the Lebanese standard of water LIBNOR 161:1999

| | Source | Calcium ($Ca^{2+}$) | Bicarbonate ($HCO_3$-) | Potassium (K) | Magnesium ($Mg^{2+}$) | Sodium ($Na^{+}$) | Nitrate ($NO_3$) | Sulfate ($SO_4{}^{2-}$) |
|---|---|---|---|---|---|---|---|---|
| | | **200 (mg/L)** | **250 (mg/L)** | **12 (mg/L)** | **50 (mg/L)** | **0.3 (mg/L)** | **45 (mg/L)** | **250 (mg/L)** |
| Rivers | Hasbani | C* | C | C | C | C | NC | C |
| | Rachiine | C | C | C | C | C | C | C |
| | Kadisha | C | C | C | C | C | C | C |
| | Awali | C | C | C | C | C | C | C |
| | Ghzayel | C | C | C | C | C | C | C |
| | Berdawni | C | C | C | C | C | C | C |
| | Litani | C | C | C | C | C | NC | C |
| Wells | Baakline | NC | NC | C | C | C | C | C |
| | Hasbaya | NC | NC | C | C | C | NC | C |
| | Kfarchakhna | C | NC | C | C | C | C | C |
| | Keserwan | C | C | C | C | C | C | C |
| | Antelias | C | C | C | C | C | C | C |
| | Fanar | NC | NC | C | C | C | C | C |
| | Lebaa | C | NC | C | C | C | NC | C |
| | Tal Amara | C | C | C | C | C | C | C |
| | Tyre | C | NC | C | C | C | C | C |

### 3.6 Summary of the bacteriological and chemical analysis in different water samples

The bacteriological, chemical elements and heavy metal analysis were determined for different water samples coming from different sources such as wells, springs, rivers as well as drinking water (table 1). The bacteriological results of the water samples (136) coming from all the sources did not meet the LIBNOR norms in 85%. The non-conformity of the water samples bacteriologically was mainly observed for the wells (90% out of 49 samples) and the rivers (100% out of 17 samples). The highest level of contamination was noted for the river samples. This could be originated due to the wastewater discharges on the river (Almeida et al. 2007). The occurrence of a high level of bacteriological contamination in well water could be due to the infiltration of waste water into aquifers or wells, resulting from the old deterioration of the sewage network in the city. The contamination of the well water could result as well from the cross-connection between domestic sewer pipes and domestic water pipes (Korfali and Jurdi 2009).

Table 6: Bacteriological, chemical elements and Heavy metals analysis in different water samples coming from wells, springs, rivers and drinking water.

The values are referred to meet the Lebanese Standard no. 1999:162 related to quality of bottled waters.

| Source of the water sample | Bacteriological analysis | | | | | Chemical elements analysis | | | | | Heavy metals analysis | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Conform | | Not conform | | Total | Conform | | Not conform | | Total | Conform | | Not conform | | Total |
| | n | % | n | % | n | n | % | n | % | n | n | % | n | % | n |
| **Wells** | 5 | 10 | 44 | 90 | 49 | 14 | 33 | 28 | 67 | 42 | 17 | 63 | 10 | 37 | 27 |
| **Springs** | 9 | 16 | 46 | 83 | 55 | 26 | 51 | 25 | 49 | 51 | 14 | 45 | 17 | 54 | 31 |
| **Rivers** | 0 | 0 | 17 | 100 | 17 | 13 | 77 | 4 | 23 | 17 | 8 | 50 | 8 | 50 | 16 |
| **Drinking** | 6 | 40 | 9 | 60 | 15 | 5 | 46 | 6 | 54 | 11 | 2 | 40 | 3 | 60 | 5 |
| **All the sources** | 20 | 15 | 116 | 85 | 136 | 58 | 48 | 63 | 52 | 121 | 41 | 52 | 38 | 48 | 79 |

The analysis of chemical elements in different water samples showed that, 52% out of 121 samples are not conform to the LIBNOR standard. The water samples coming from the wells are shown to present the high percentage of non-conformity (67%), followed by the drinking water (54%).The high concentrations in chemical elements may have direct Health implications (Reimann et al. 2003). The high level of contaminants in the well water can pollute surface water. Therefore, water must be analyzed to recognize the unwanted constituents, and consequently treat the water (Reimann et al. 2003).

When compared to the National LIBNOR standard of heavy meals in water, it was shown that 48% out of 79 samples are not conform to the standard. The non-conformity was mainly noted for the drinking water (60%). Noting that the other water sources presented non-conformities in heavy metals. Drinking water is produced for different sources such as surface water, groundwater and springs water (Kim, Amy, and Karanfil 2015). The high level of heavy metals in drinking water pose a threat to human health (Chowdhury et al. 2016). This contamination can be attributed to the source of water, the treatment as well as the length and materials of the pipes, which can significantly contribute to the concentrations of heavy metals in drinking water (Chowdhury et al. 2016). The high amount of heavy metals in water can consequently be expected in the food chain and food cultivated in the Lebanese Urban areas, Therefore, the protection of diets from these hazards should be considered as one of the essential and priority public health functions in any country (Nasreddine et al. 2006). This could be due by using advanced technologies for heavy metal removal.

Table 1 shows that 85% of the water samples, coming from the different sources, fail to pass the microbiological LIBNOR norm of water. The non-conformity for the chemical elements and heavy metals was respectively 52% and 48%. This comparison emphasizes on the importance of analyzing the different sources of water as well as documenting the chemical elements concentration and variation in different Lebanese Urban cities. The results highlighted the need of promoting awareness among end users about their water quality, to provide safe adequate water supplies as well as proper management of water in Lebanese Urban cities. Adopting such activities will protect and promote public health, reduce disease burden and ensure improve the socioeconomic growth.

## 4 CONCLUSIONS

This paper investigated the state of research on bacteriological profile, chemical elements and heavy metals in different sources of water such as wells, springs, rivers and drinking water. The non-conformity of the water sources with the Lebanese Standard of water ranges between 48% to 85% for the different parameters assessed. Water samples taken from some wells and rivers was shown to be exceeding the Lebanese norms in mercury, nitrate, calcium and bicarbonate. Bases on the results of the study, it is evident that the situation in different Lebanese Urban Cities is deteriorating at a fast pace. It is essential to interfere in order to provide a safe domestic water, free of bacteriogical and chemical contaminants. Advanced technologies of water treatment should be proposed for the contaminants removal.

The results indicated that the urban activity produces a serious and negative effect on the water quality, consequently leading to a sanitary risk. An intervention plan should be adopted to secure a safe water supply, through upgrading the water quality profile as well as consumer awareness.

This study highlighted the importance of documenting bacteriological and chemical element concentration and variation of different sources of water. This can provide a fingerprint to the different types of water according to the geographical location, allowing a better quality classification of the different water sources in the Lebanese Urban cities.

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## REFERENCES

- Almeida, Cesar A., Silvya Quintar, Patricia González, and Miguel A. Mallea. 2007. “Influence of Urbanization and Tourist Activities on the Water Quality of the Potrero de Los Funes River (San Luis - Argentina).” *Environmental Monitoring and Assessment* 133(1–3):459–65.
- Ashbolt, Nicholas John. 2004. “Microbial Contamination of Drinking Water and Disease Outcomes in Developing Regions.” Pp. 229–38 in *Toxicology*, vol. 198.
- Assaf, H. and M. Saadeh. 2007. “Assessing Groundwater Quality Conditions in the Upper Litani River Basin Utilizing Geostatistical Analysis Tools.” *WIT Transactions on Ecology and the Environment* 104:483–92.
- Chowdhury, Shakhawat, M. A.Jafar Mazumder, Omar Al-Attas, and Tahir Husain. 2016. “Heavy Metals in Drinking Water: Occurrences, Implications, and Future Needs in Developing Countries.” *Science of the Total Environment* 569–570:476–88. Retrieved (http://dx.doi.org/10.1016/j.scitotenv.2016.06.166).
- Chuu, Jiunn Jye, Shing Hwa Liu, and Shoei Yn Lin-Shiau. 2007. “Differential Neurotoxic Effects of Methylmercury and Mercuric Sulfide in Rats.” *Toxicology Letters* 169(2):109–20.
- Edwards, Marc. 2014. “Fetal Death and Reduced Birth Rates Associated with Exposure to Lead-Contaminated Drinking Water.” *Environmental science & technology* 48(1):739–46.

- Fadiran, A. O. and S. M. Mamba. 2005. "Analysis of Nitrates and Nitrites in Some Water and Factory Effluent Samples from Some Cities in Swaziland." *Bulletin of the Chemical Society of Ethiopia* 19(1):35–44.
- Fewtrell, Lorna. 2004. "Drinking-Water Nitrate, Methemoglobinemia, and Global Burden of Disease: A Discussion." *Environmental Health Perspectives* 112(14):1371–74.
- Harakeh, Steve, Hadi Yassine, Shady Hajjar, and Mutasem El-Fadel. 2006. "Isolates of Staphylococcus Aureus and Saprophyticus Resistant to Antimicrobials Isolated from the Lebanese Aquatic Environment." *Marine Pollution Bulletin* 52(8):912–19.
- Harikumar, P. S., U. P. Nasir, and M. P. Mujeebu Rahman. 2009. "Distribution of Heavy Metals in the Core Sediments of a Tropical Wetland System." *International Journal of Environmental Science and Technology* 6(2):225–32.
- Jurdi, Mey, Samira Ibrahim Korfali, Yester Karahagopian, and Brian E. Davies. 2001. "A Prototype Study for the Management of Surface Water Resources, Lebanon." *Water Policy* 3(1):41–46.
- Kim, Daekyun, Gary L. Amy, and Tanju Karanfil. 2015. "Disinfection by-Product Formation during Seawater Desalination: A Review." *Water Research* 81:343–55.
- Korfali, Samira Ibrahim and Mey Jurdi. 2009. "Provision of Safe Domestic Water for the Promotion and Protection of Public Health: A Case Study of the City of Beirut, Lebanon." Pp. 283–95 in *Environmental Geochemistry and Health*, vol. 31.
- Massoud, M. a, a Al-Abady, M. Jurdi, and I. Nuwayhid. 2010. "The Challenges of Sustainable Access to Safe Drinking Water in Rural Areas of Developing Countries: Case of Zawtar El-Charkieh, Southern Lebanon." *Journal of Environmental Health* 72(10):24–30. Retrieved (http://ovidsp.ovid.com/ovidweb.cgi?T=JS&CSC=Y&NEWS=N&PAGE=fulltext&D=med5&AN=20556940 http://sfx.scholarsportal.info/uhn?sid=OVID:medline&id=pmid:20556940&id=doi:&issn=0022-0892&isbn=&volume=72&issue=10&spage=24&pages=24-30&date=2010&title=Journal+of+Envi).
- Mcheik, Amale, Aida Ibrik, Rawane Mehdi, Jamil Houhou. 2017. "Assessment of the Domestic Water Profile of the Region Surrounding Al-Ghadir River, Mount Lebanon." *International Journal of Environmental Monitoring and Analysis* 5(5):123–27.
- Mohiuddin, K. M., Y. Ogawa, H. M. Zakir, K. Otomo, and N. Shikazono. 2011. "Heavy Metals Contamination in Water and Sediments of an Urban River in a Developing Country." *International Journal of Environmental Science and Technology* 8(4):723–36. Retrieved (http://www.ijest.org/jufile?c2hvd1BERj01Mjk=&ob=42f2ed8db7b1e7d145e031745ab965dd&fileName=full_text.pdf).
- Mohiuddin, K. M., H. M. Zakir, K. Otomo, S. Sharmin, and N. Shikazono. 2010. "Geochemical Distribution of Trace Metal Pollutants in Water and Sediments of Downstream of an Urban River." *Int. J. Environ. Sci. Tech* 7(1):17–28. Retrieved (http://www.sid.ir/EN/VEWSSID/J_pdf/92220100103.pdf).
- Nasreddine, L. et al. 2006. "Dietary Exposure to Lead, Cadmium, Mercury and Radionuclides of an Adult Urban Population in Lebanon: A Total Diet Study Approach." *Food additives and contaminants* 23(6):579–90.
- Ramadan, Hamzeh H., R.Edward Beighley, and Amruthur S. Ramamurthy. 2013. "Sensitivity Analysis of Climate Change Impact on the Hydrology of the Litani Basin in Lebanon." *International Journal of Environment and Pollution* 52(1/2):65. Retrieved (http://www.inderscience.com/link.php?id=56359).
- Reimann, Clemens et al. 2003. "Drinking Water Quality in the Ethiopian Section of the East African Rift Valley I--Data and Health Aspects." *The Science of the total environment* 311(1–3):65–80.
- Semerjian, Lucy A. 2011. "Quality Assessment of Various Bottled Waters Marketed in Lebanon." *Environmental Monitoring and Assessment* 172(1):275–85. Retrieved (https://doi.org/10.1007/s10661-010-1333-7).
- Sener, Göksel et al. 2007. "Ginkgo Biloba Extract Protects against mercury(II)-Induced Oxidative Tissue Damage in Rats." *Food and chemical toxicology : an international journal published for the British Industrial Biological Research Association* 45(4):543–50. Retrieved (http://www.sciencedirect.com/science/article/pii/S0278691506002195).
- Servais, P., G. Billen, A. Goncalves, and T. Garcia-Armisen. 2007. "Modelling Microbiological Water Quality in the Seine River Drainage Network: Past, Present and Future Situations." *Hydrology and Earth System Sciences* 11(5):1581–92.
- WHO, World Health Organization (WHO), WHO, and World Health Organization (WHO). 2011. *WHO Guidelines for Drinking-Water Quality*.
- Yoshida, Takahiko, Hiroshi Yamauchi, and Gui Fan Sun. 2004. "Chronic Health Effects in People Exposed to Arsenic via the Drinking Water: Dose-Response Relationships in Review." *Toxicology and Applied Pharmacology* 198(3):243–52.