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Assessment of Chemical and Microbiological Drinking Water of Beirut and Mount Lebanon

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Abstract
Lebanon is known for its abundant water resources, but it faces significant challenges with water supply shortages, particularly in delivering water to residential areas and public facilities. This problem is compounded by a high rate of pollution, both in pipelines and bottled water. To address the issue of water-related diseases, this research was conducted to assess the water quality of 79 drinking water samples from Beirut and Mount Lebanon using the Inductively Coupled Plasma – Optical Emission Spectrometry (ICP-OES) with Ultra Sonic Nebulizer (USN) method. The study found that most element concentrations in the water samples are within the acceptable range set by the World Health Organization (WHO). However, four elements were highlighted as areas of concern: sodium, arsenic, mercury, and calcium, as their concentrations were outside the accepted WHO range. Specifically, 23% of sites showed high mercury concentrations from various potential sources, 76% of sites had elevated arsenic levels, and 91% of sites had low calcium concentrations, indicating weak mineralization in the drinking water. Additionally, 20% of sites had high sodium concentrations, and 9% had high calcium concentrations due to the presence of carbonate rock reservoirs, particularly limestone, which increases water hardness. The microbiological analysis of water samples showed that 60.76% of the samples contained bacteria. Among the samples, 46% were contaminated by total coliform, and 33% showed contamination by fecal coliform. Additionally, 30% of the samples contained Pseudomonas aeruginosa, and 39% were contaminated with E. coli. These findings indicate that a significant percentage of the tested water samples have microbial contamination, posing potential health risks to consumers. Proper water treatment and monitoring measures are essential to ensure the safety and quality of drinking water and to reduce the incidence of waterborne diseases.
Keywords: Lebanon, Drinking water, Pollution, heavy metals, treatment.
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1. Introduction:

Lebanon, located in the Middle East, is facing severe challenges due to the effects of climate change, particularly on its water resources. The availability of water is declining, leading to hydrological droughts. Over the last four decades, Lebanon has experienced a significant decrease of about 23-29% in water availability from various sources. The World Economic Forum has identified a water crisis as the fourth-largest global risk, and this crisis is already affecting many countries in the Middle East, including Lebanon, due to arid climates, geographical constraints, and poor resource management, which leads to high water demands that cannot be met by limited resources (Myers and Whiting, 2019).

Lebanon's unique geography sets it apart from surrounding Middle Eastern regions, despite its relatively small surface area. It is endowed with various water resources, such as rivers, springs, lakes, snow, and numerous underground aquifers, rock formations, and karstic conduits. However, challenges persist in effectively managing these resources, exacerbated by population growth and changing climatic conditions. Mismanagement has worsened the situation, and credible estimates of water resources are still lacking.

Lebanon consists of 43 major watercourses, with 14 flowing waters throughout the year, are struggling to provide sufficient renewable water, falling below the water stress level of 1,000 m^3 per capita per year (Shaban, 2020). Projections indicate a further decline in water resources, reaching around 839 m^3/cap/yr. by 2015 (MoEW, 2012), with the latest statistics from 2017 showing water availability at approximately 704 m^3/cap./yr. *(World Bank data, 2023).* The supply of water to residential areas and public facilities has visibly decreased, resulting in shortages. Concurrently, pollution levels have risen significantly in both tap and bottled water, further exacerbating the water crisis in Lebanon.

In recent times, there has been an alarming decline in water resource supply, with reductions in river and spring discharge by about 55-60%, a 15% regression in snow cover area, and a decline in the water table by several meters. Groundwater aquifers are also experiencing a decrease in discharge by about 30% (Shaban, 2020). Additionally, pollution is pervasive, with very few sources of pure water in Lebanon. Rivers are contaminated, and several aquifers show abnormal pollution levels (Nehme et al, 2021, Nehme and Haydar, 2019; Nehme et al, 2020; Sawaya et al, 2021). Drinking water quality in Lebanon has become a cause for concern due to unacceptable levels of contamination (Nehme et al, 2021).

To address these issues, the present study aims to analyze the chemical and microbiological quality of drinking water from various sources in the capital city of Beirut and Mount Lebanon. The goal of this study is to assess the extent of contamination and suitability for consumption. Based on the results obtained from analyzing representative samples of drinking water, recommendations will be provided to improve the water quality and address the critical geo-environmental challenges posed by the water deficit in Lebanon.

2. Materials and Methods

2.1 Study Area

Around two million people live in the governorates of Beirut and Mount Lebanon, which together make almost half of Lebanon's population. Most of the Lebanese governorates are urban or peri urban. However, despite its vast territory, Mount Lebanon includes numerous isolated and rural regions.

Mount-Lebanon is an elevated region situated mainly in the northern half of Lebanon, where it extends adjacent to the Mediterranean Sea. It is usually separated from the coast by flat ribbons of agricultural lands, forming the coastal plains, which are quite narrow with a width of less than 2 km. It is characterized by three main zones: a) Low altitude (200-1200 m), b) Moderate altitude (1200-1800 m), and c) High altitude (> 1800 m). Mount-Lebanon, with a rugged topography and dominant green cover and forests, is known as a humid region where average annual precipitation rate ranges between 700 and 1500 mm and snow covers the high-altitude zone for a couple of months. The average annual temperature has been estimated between 18 and 26 °C, and this is associated with a relative humidity between 60 and 80%.

Greater Beirut or "Greater Beirut is situated in Lebanon's central coastline region", representing the capital of Lebanon (Fig.1), has a total area of 233 km^2, or 2.2% of Lebanon's total land area, which includes 67 km^2 of urbanized area. Beirut is home to about 11% of the country's residents, while 27% dwell there and its surrounding suburbs. It reaches a height of 750 meters above sea level (Faour and Mhawej, 2014). Greater Beirut is characterized by the Mediterranean climate (Faour and Mhawej 2014; OCHA 2016; UN 2020; Yamout and El-Fadel, 2005, Saad, et al, 2022; Badran, 2016), with an average population density of 6,200 people/km^2, and is densely populated.

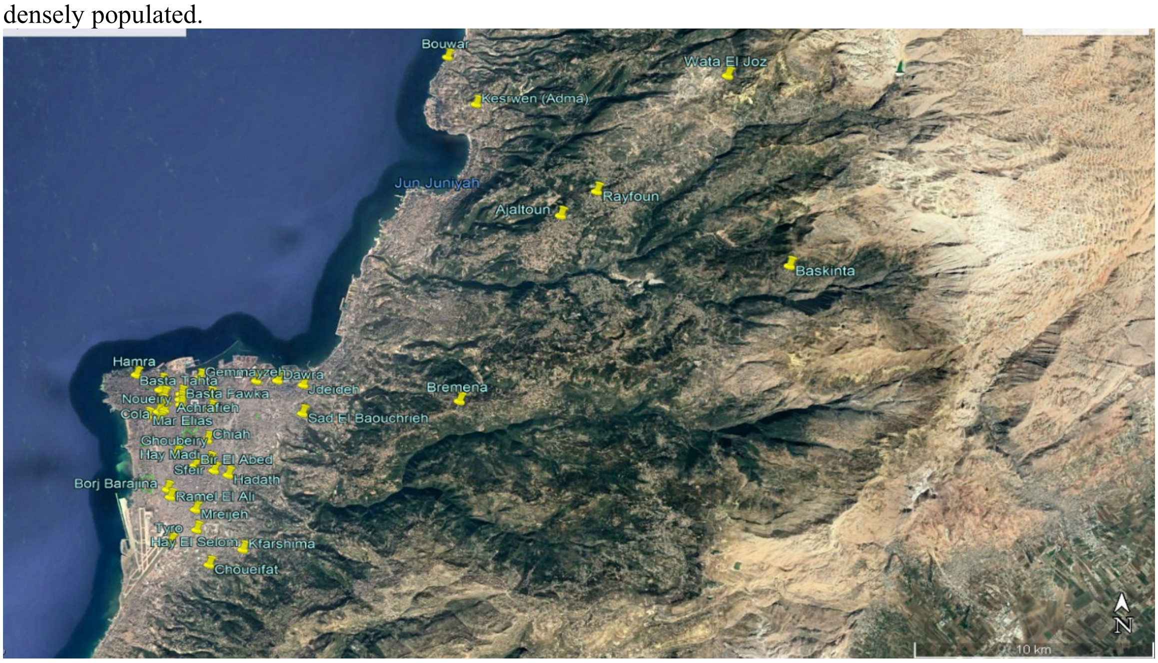

Figure 1. Location of the sampling in Beirut and Mount Lebanon districts. (Google earth, 2023)

2.2 Sampling of water

Water samples were collected from various areas in Beirut and Mount Lebanon at the mentioned sites (Fig. 2 and Fig. 3). To adequately assess the pollution factor from each site, 2000 ml of water were collected. Furthermore, each sample was replicated twice from each site. Polyethylene bottles were used to conserve the water samples.

The sampling and collection method followed the Standard Methods by WHO and the Lebanese standard for drinking water (WBD, 2016).

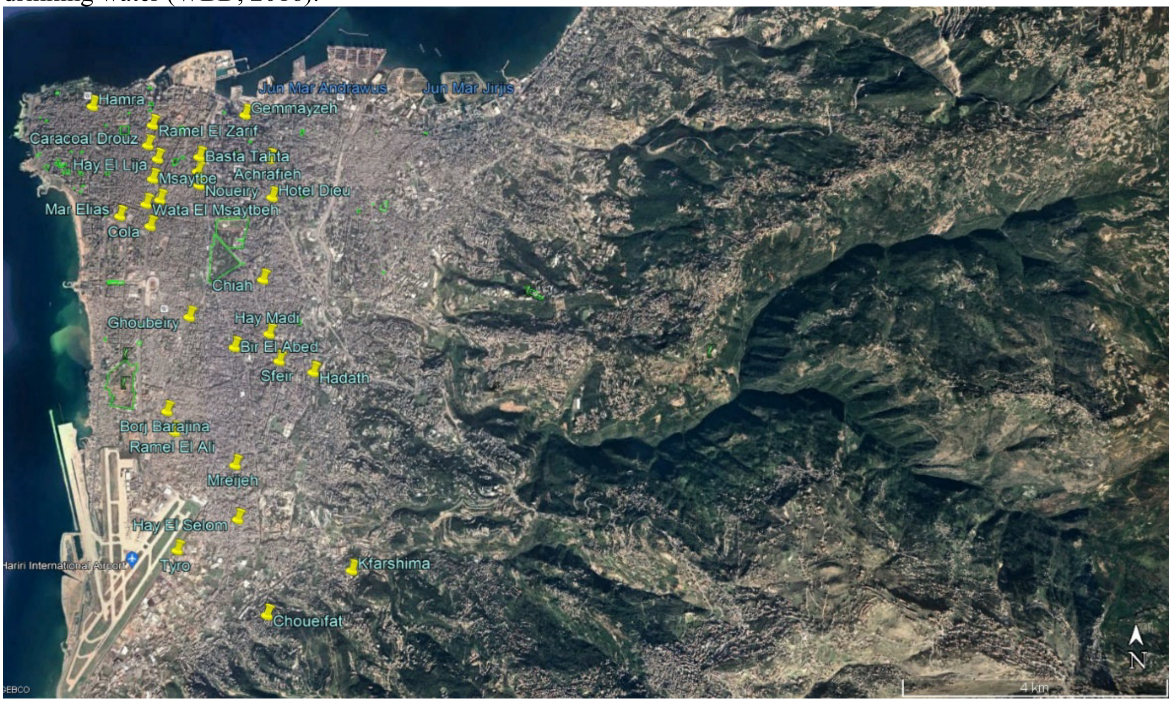

Figure 2. Location of the sampling in Beirut districts. (Google earth, 2023)

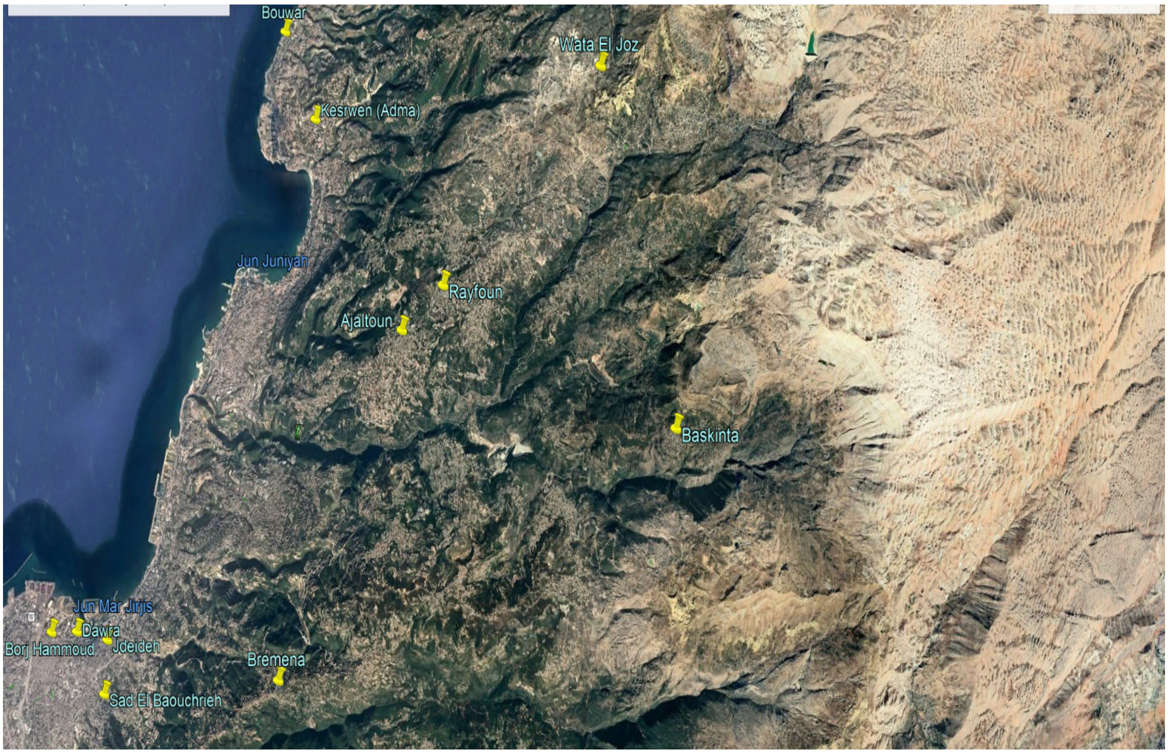

Figure 3. Location of the sampling in Mount Lebanon districts. (Google earth, 2023)

A total of 79 drinking water samples were collected from 39 different sites (multiple samples were collected at several sites). These are Ajaltoun, Baskinta, Reyfoun, Hotel Dieu, Gemayze, Dawra, Jdeideh, Borj Hammoud, Hadath, Bremena, Kesrwen (Adma), Kesrwen (Bouwar), Mar Elias, Sad el Bouchrieh (2 samples), Wata el Joz, Noueiry (2 samples), Ramel el Ali, Wata Msaytbe, Kfarshima, Tyro, Choueifat (8 samples), Mreijeh, Achrafieh (4 samples), Msaytbe (4 samples), Borj Barajina (2 samples), Sfeir, Cola, Corniche el Mazraa (2 samples), Ghoubeiry (3 samples), Chiah (4 samples), Hamra (7 samples), Caracoal El Drouz (3 samples), Ramel El Zarif (3 samples), Hay El Lija (2 samples), Hay Madi (2 samples), Bir El Abed, Basta Fawka, Basta Tahta (3 samples), Hay El Selom (3 samples).

Drinking water samples were manually taken from each of the seventy-nine sources. For the chemical characterization, the samples were kept in 2 L polyethylene plastic bottles (one bottle from each source), and one sterile cup was used for the microbiological investigation. Neither before nor after the water sampling, any detergent was applied to preserve or sterilize the bottles. Bottles for sampling were supplied with 2% nitric acid to be acidified (pH < 2) and stored in portable coolers. For the microbiological analysis, 500 ml was collected in borosilicate glass bottles.

2.3 Methodology

The chemical and microbiological analysis was performed following standard techniques and was analyzed at RBML laboratory. The chemical and microbiological parameters of water quality were carried out by different methods as shown in Table 1.

Table 1. Parameters tested and analytical methods.

Parameters	Methods
E. coli / Total Coliforme / Focal Coliforme	Conventional- Membrane Filtration (Afnor - BRD 7/20)
Pseudomonas Aeruginosa	Conventional- Membrane Filtration (Afnor - BRD 7/21)
Heavy metals and cations	ICP-OES Atomic Emission Spectroscopy

The concentrations of sodium, Arsenic, Mercury, and Calcium were measured using the Inductively Coupled Plasma – Optical Emission Spectrometry (ICP-OES) with Ultra Sonic Nebulizer (USN) (Model: Perkin Elmer Optima 3000). The samples were filtered by filtration system through a membrane filter with a pore size of 0.45µm before analyses using Standard Methods (APHA 1992).

2.4 Statistical analysis

The statistical analysis was determined by the R - Program. Six continuous active variables representing the pollutants whose descriptive analysis showed that these variables exceeded acceptable and international standards. The six variables are total coliforms, fecal coliforms, *Pseudomonas Aeruginosa*, *Escherichia coli* (E. coli), sodium, arsenic, mercury, and calcium.

R is a language and environment for statistical computing and graphics. It is a *GNU (*GNU stands for Gnu's Not Unix), One of R's advantages is the ease with which well-designed publication-quality plots can be produced, including mathematical symbols and formulae where needed. Concern has been taken over the defaults for the minor design choices in graphics, but the user retains full control (Grolemond, G., and Wichham, H. 2017).

R is available as Free Software under the terms of the Free Software Foundation's GNU General Public License in source code form. It compiles and runs on a wide variety of UNIX platforms and similar systems (including FreeBSD and Linux), Windows, and MacOS (Dalgaard, 2008). Multivariate statistical analyses were performed in this study to reflect the degree of dispersion distribution of the different variables. PCA was carried out by using the R-program, and FA was carried out to assess the relationship between different variables of samples using XLSTAT.

3. Results and Discussion:

Seventy-nine drinking water samples were evaluated, and all samples were found to be within WHO guidelines and Lebanese standards for drinking water, except for four variables Arsenic, Mercury, Calcium, and Sodium.

The microbiological analysis of water samples revealed the presence of Bacteria in 60.76 % of samples. They reflect a very high risk in water sampling as shown in Table 2. Up to 46% of samples are contaminated by total coliform, and up to 33% by fecal coliform; while 30% are contaminated with *Pseudomonas Aeruginosa* and 39% are contaminated by E. coli.

Table 2. Microbiological analysis of water samples.

	Total Coliforms *(MPN/100 ml)*	Fecal Coliforms *(MPN/100 ml)*	Pseudomonas Aeruginosa *(MPN/100ml)*	E. coli *(MPN/100ml)*
N valid	79	79	79	79
Missing	0	0	0	0
Existence	46%	33%	30%	39%
Lack	54%	67%	70%	61%

The presence of microbiology infection in water samples could be brought on by contamination in an outdated pipelining system, back siphoning, a drainage system, or a break in the water supply pattern. Moreover, negligence could be to blame for bacterial infection.

The findings revealed that 16 sites—Msaytbe, Chiyah, Hamra, Wata El Joz, Choueifat, Kfarshima, Tyro, Hay el Selom, Achrafieh, Gemayzeh, Dawra, Hadath, Baskinta, Borj El barajina, Sfeir, and Ramel El Ali were contaminated with total coliform. The most contaminated locations with total coliform, fecal coliform, and pseudomonas aeruginosa include Chiyah, Choueifat, Hamra, and Borj Barajina. The results of the microbial investigation on water sample showed that the total coliform, fecal coliform, E.coli and Pseudomonas Aeroginosa content of the water at those sampling locations made it unhealthy. It was found that the majority of the tested water had increased levels of bacteria making it unsafe to drink. The data describe that there is a high risk in tap water.

3.1. Correlation matrix:

The linear correlation coefficient gives a measure of the strength and direction of the linear relationship between two variables. Its calculation is quite complex; and therefore, a calculator or software is often used. The interpretation considered the following correlation coefficients:

- The correlation coefficient is between −1 and 1.
- The closer the coefficient is to 1, the stronger the positive linear relationship between the variables.
- The closer the coefficient is to −1, the stronger the negative linear relationship between the variables.

The closer the coefficient is to 0, the weaker the linear relationship between the variables.

Table 3 shows the total independence between all the variables except the Fecal Coliform, which shows similarity with Pseudomonas-Aeruginosa.

Table 3. Correlation matrix between microbiological parameters.

	Total Coliform *(MPN/100ml)*	Fecal Coliform *(MPN/100ml)*	Pseudomonas. Aeruginosa *(MPN/100ml)*	E. coli *(MPN/100ml)*
Total Coliforme *(MPN/100ml)*	1			
Fecal Coliforme*(MPN/100ml)*	0.084	1		
Pseudomonas Aeruginosa (*MPN/100ml)*	0.0068	0.40	1	
E. coli *(MPN/100ml)*	-0.01	-0.02	-0.02	1

3.2. Concentration of Cations in water

The maximum sodium value of 2195.22 ppm was found in Choueifat 8, while the minimum value of 0.61 ppm was found in Hamra 3 (as shown in Table 4). The mean sodium concentration is 118.2509 ppm, and the standard deviation is 219.468 ppm, which is much greater than 1, indicating that the sodium values are widely scattered around the mean. A total of 16 sites (20.25% of all sites) have a very high sodium concentration since the maximum acceptable sodium value is 150 ppm (as shown in Fig. 4 and Fig. 5).

In the case of calcium, Msaytbe 4 had the highest calcium value of 612.85 ppm, while Borj Barajina 2 had the lowest calcium value of 0.61 ppm (as shown in Table 4). The average calcium value is 95.6426 ppm. The data are skewed toward the mean because the standard deviation is 9.408, which is larger than 1. Moreover, seven sites (8.86% of all sites) have calcium concentrations significantly higher than the maximum allowed limit of 200 ppm (as shown in Fig. 4 and Fig. 5).

Table 4. Table showing the results of Sodium and Calcium.

	Sodium (ppm)	Calcium (ppm)
N valid	79	79
Missing	0	0
Min	0.61 (Hamra 3)	0.61 (Borj Barajina 2)
Max	2195.22 (Choueifat 8)	612.85 (Msaytbe 4)
Mean	129.3	105.4

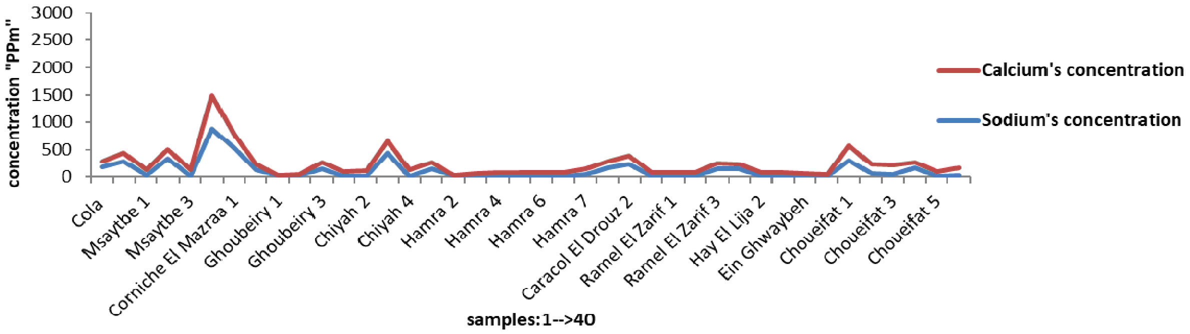

Figure 4. Graph showing the concentration of Calcium and Sodium in the analyzed water samples in 40 samples at Beirut and Mount Lebanon.

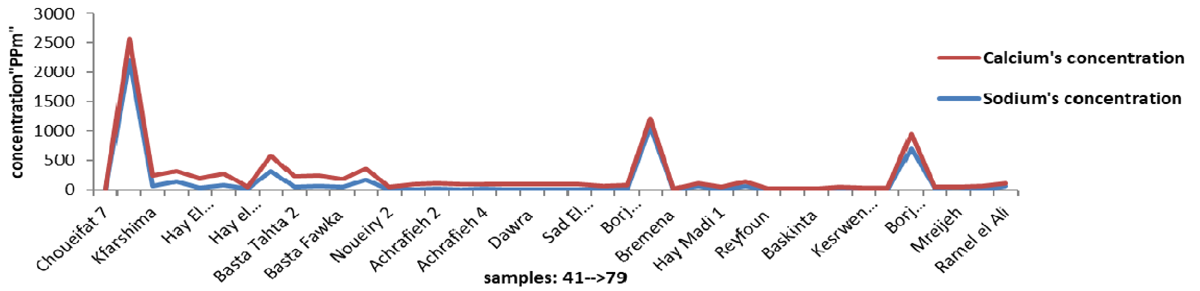

Figure 5. Graph showing the concentration of Calcium and Sodium in the analyzed water samples from number 41 to 79 at Beirut and Mount Lebanon.

3.3. Heavy metals: Arsenic and Mercury

The concentration of arsenic in Cornich el Mazraa is the highest at 0.17 ppm, whereas Sad El Bouchrieh 2, Hay Madi 2, Ramel el Ali, and Borj Barajina 2 are completely devoid of arsenic, with the lowest concentration being 0 ppm (as shown in Table 5). The mean concentration of arsenic is 0.007 ppm, and the standard deviation is 0.03427 ppm, which is much less than 1. This indicates that the data is not distributed around the mean. Notably, since the maximum allowed level of arsenic is 0.05 ppm, a significant number of sites, specifically 73 sites (or 76%), have extremely high arsenic concentrations (as shown in Fig.6 & 7).

Table 5. Table showing the results of Arsenic.

Arsenic		
N valid		79
missing		0
Min	0	Sad El Bouchrieh 2 Hay Madi 2 Borj Barajina 2 Ramel el Ali Choueifat 8
Max	0.17	Corniche El Mazraa 2
Mean	0.07791	

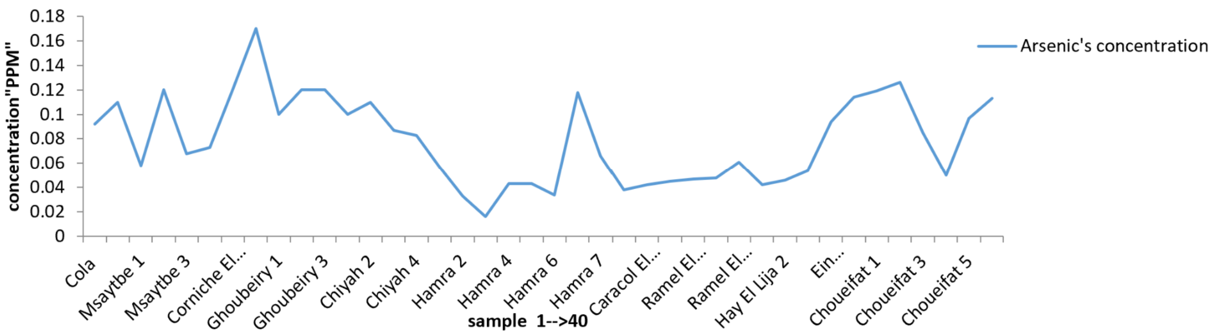

Figure 6. Graph showing the concentration of Arsenic in the analyzed water samples at Beirut and Mount Lebanon. (samples from 1 to 40).

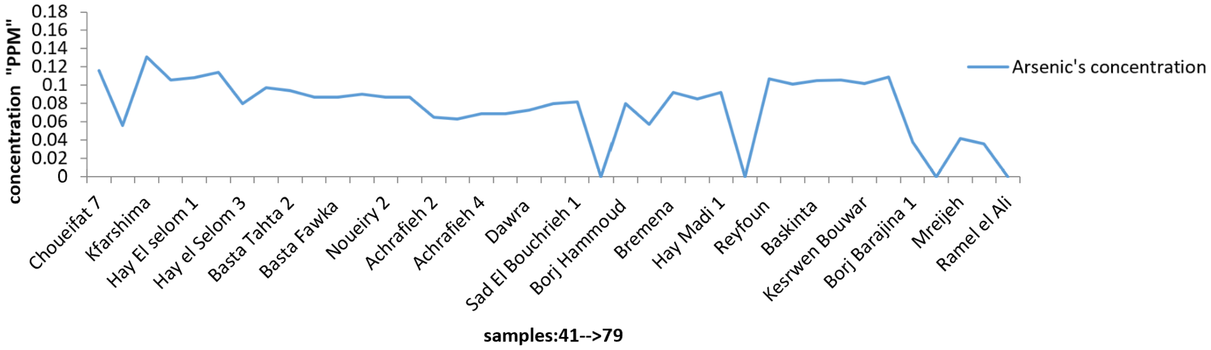

Figure 7. Graph showing the concentration of Arsenic in the analyzed water samples at Beirut and Mount Lebanon. (samples from 41 to 79)

The maximum value of mercury is 0.002 ppm, which is present at 24 sites in 12 regions, including Cola, Msaytbe, Ghoubeiry, Chiyah, Hamra, Ramel el Zarif, Basta Tahta, Achrafieh, Dawra, Jdeideh, Sad el Bouchrieh, and Hay Madi, accounting for 23% of all sites (as shown in Fig. 8 & 9). All other values are below the maximum accepted value for mercury, which is 0.001 ppm. The mean mercury concentration is 0.0009 ppm, and the standard deviation is 0.0006 ppm, which is much less than 1, indicating that the values are not widely scattered around the mean (as indicated in Table 6).

Many locations, including Cola, Choueifat, Achrafieh, Borj Hammoud, and others, have high mercury concentrations due to hospital discharges, dental office discharges, and specific laboratory emissions. Emissions from polluted materials, such as the crematory ovens' bricks, also contribute to the presence of mercury.

Mercury is a naturally occurring element found in soil, water, and air. Even in small doses, mercury exposure can have significant health effects and pose risks to the development of unborn children and early childhood. It can negatively impact the neurological, digestive, and immunological systems and the lungs, kidneys, skin, and eyes. The World Health Organization (WHO) considers mercury as one of the top ten substances or chemical groups of significant public health concern (WHO, 2017).

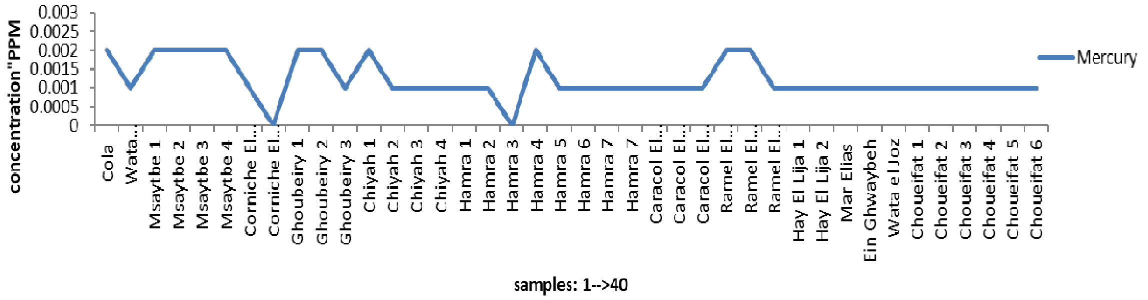

Figure 8. Graph showing the concentration of Mercury in the analyzed samples at Beirut and Mount Lebanon. (samples from 1 to 40).

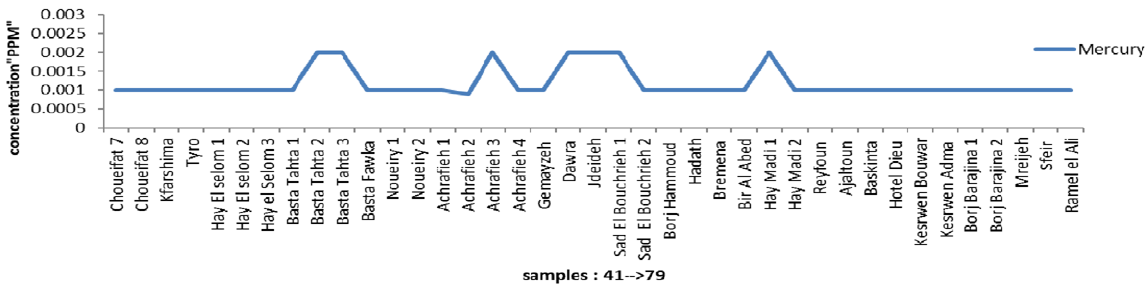

Figure 9. Graph showing the concentration of Mercury in the analyzed samples at Beirut and Mount Lebanon. (samples from 41 to 79).

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Table 6. Table showing the results of Mercury.

Mercury	
N valid	79
Missing	0
0	3%
0.0009	1%
0.001	73%
0.002	23%

3.4. Analysis of the Main Components

Principal Component Analysis (PCA) is a statistical technique used to summarize the information content in large data tables by creating a smaller set of "summary indices" or principal components (Mahapatra, et. al, 2012, Grolemond and Wichham, 2017; Dalgaard, 2008). These components are easier to visualize and analyze than the original data. The PCA involves the diagonalization of the inertia matrix, and the eigenvalues obtained from this process correspond to the amount of variance intercepted by the factorial axes.

In PCA, it is select the largest eigenvalues, denoted as λi, to determine the number of factorial axes required to establish a reduced dimension subspace. The choosing axes with the maximum inertia is akin to constructing new variables associated with the axes of maximum variance. The principal axes of inertia, also known as direction axes, are the eigenvectors of the matrix of variances-covariance, which are normalized to decide on the number of axes to retain in PCA, several methods can be used, such as:

1. Scree Plot: This plot displays the eigenvalues against the corresponding principal components. The point where the plot levels off or "flattens" indicates the optimal number of components to retain.
2. Kaiser Criterion: According to this criterion, only eigenvalues greater than 1 should be retained as they explain more variance than a single original variable.
3. Modified Kaiser Criterion: This criterion is an adjusted version of the Kaiser criterion and helps in determining the number of components to keep based on the eigenvalues.
4. Anderson Criterion: The Anderson criterion uses a statistical test to determine the number of components to retain.

By applying these criteria, it could be decided how many principal components to be considered in the PCA, allowing for a reduced dimension representation of the original data while retaining the most significant variance.

3.4.1. Active variables.

According to table 7 of coordinates of the active variables of sodium, arsenic, mercury, and calcium, it can be argued that:

- All variables are positively influential on axis 1.
- All variables except 'Na' are positively influential on the axis.

Table 7: Rotated factor loadings of principal components on chemical parameters.

Parameters	F 1	F 2
Na	0.900	-0.230
As	0.114	0.761
Hg	0.066	0.630
Ca	0.922	0.085

According to table 8 of coordinates of the active variables of microbiology tests, it can be argued that:

- All variables are positively influenced on axis 1 except 'Ecoli'.
- All variables except 'Tot_col' have a positive influence on axis 2.

Table 8: Rotated factor loadings of principal components on microbiological parameters.

Parameters	F1	F2	F3	F4
Tot_Col	0.188	-0.676	0.705	-0.104
Fec Col	0.837	0.052	0.027	0.544
Pseud_Aero	0.819	0.179	-0.115	-0.533
Ecoli	-0.088	0.717	0.691	-0.004

3.4.2. Circle of correlation:

The circle of correlations is not only a symbolic representation; it is the projection of all the reduced center variables onto the subspace generated by the pair of principal components. In the space of variables, this circle is therefore the exact counterpart of the projection of individuals onto the first main plane. The F1-F2 duo accounts for more than 67.80 % of chemical parameters (Fig.10) and more than 60.52 % for microbiology parameters (Fig. 11). Based on these percentages, the processes governing the chemical development of the region's water are essentially in these components.

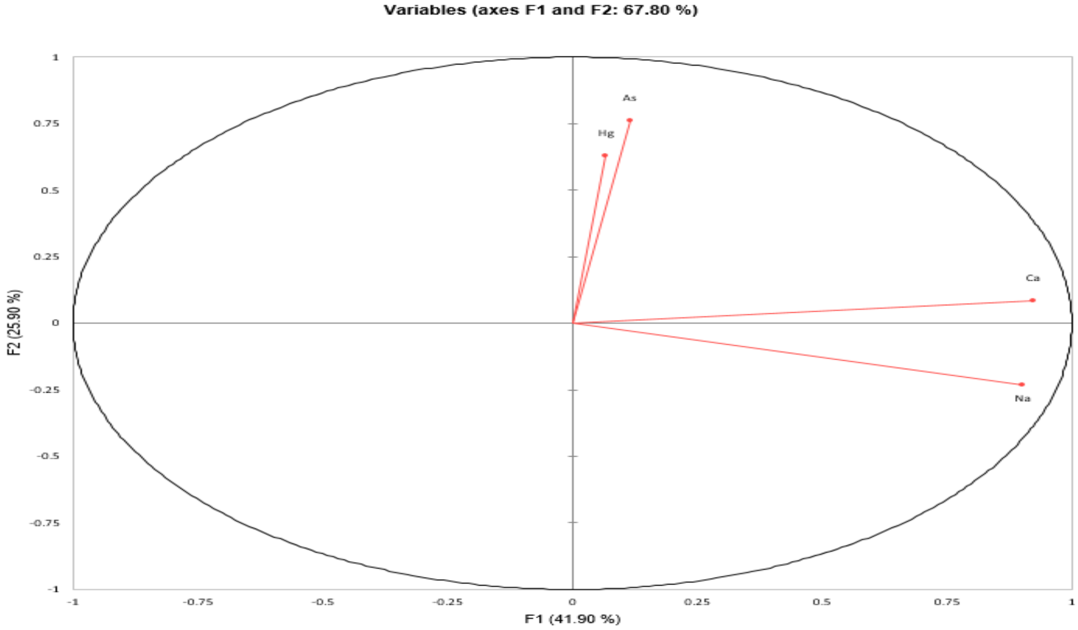

Figure 10. The circle of correlation for chemical parameters

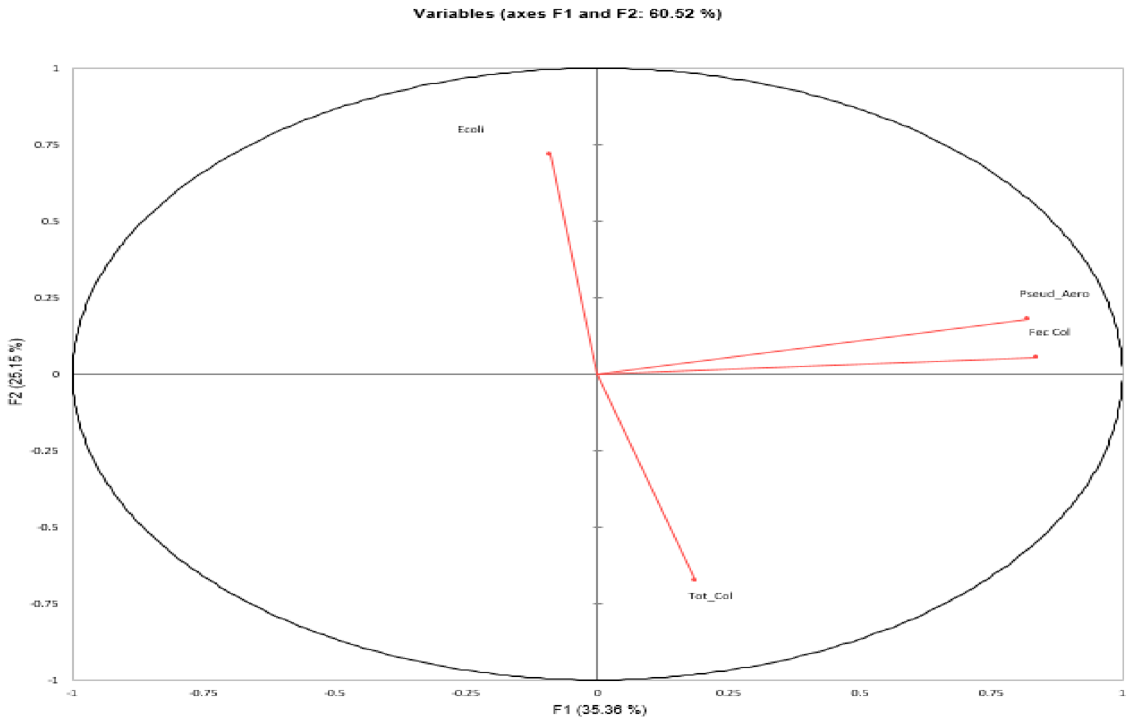

Figure 11. The circle of correlation for microbiology parameters.

3.4.3. Classification of Individuals

Figure 12 shows the classes of individuals concerning the cations and heavy metals parameters. It can be noticed the following sequence of classes:

- Class 1/4 (weight = 47, number = 47)

Class 1 consists of 47 Sites (60.2% of sites), it is characterized by a high concentration of Mercury and Arsenic.

- Class 2/4 (weight = 2, number = 2)

Class 2 consists of 2 Sites (2.5% of sites), and it is characterized by the extremely high concentration of Sodium and Calcium.

• Class 3/4 (weight = 6, number = 6)
Class 3 consists of 6 Sites (7.5% of sites), it is characterized by the high concentration of Sodium and Calcium.
• Class 4/4 (weight = 23, number = 23)
Class 4 consists of 23 Sites (28.2% of sites), it is characterized by the low concentration of Sodium, Calcium and Arsenic.

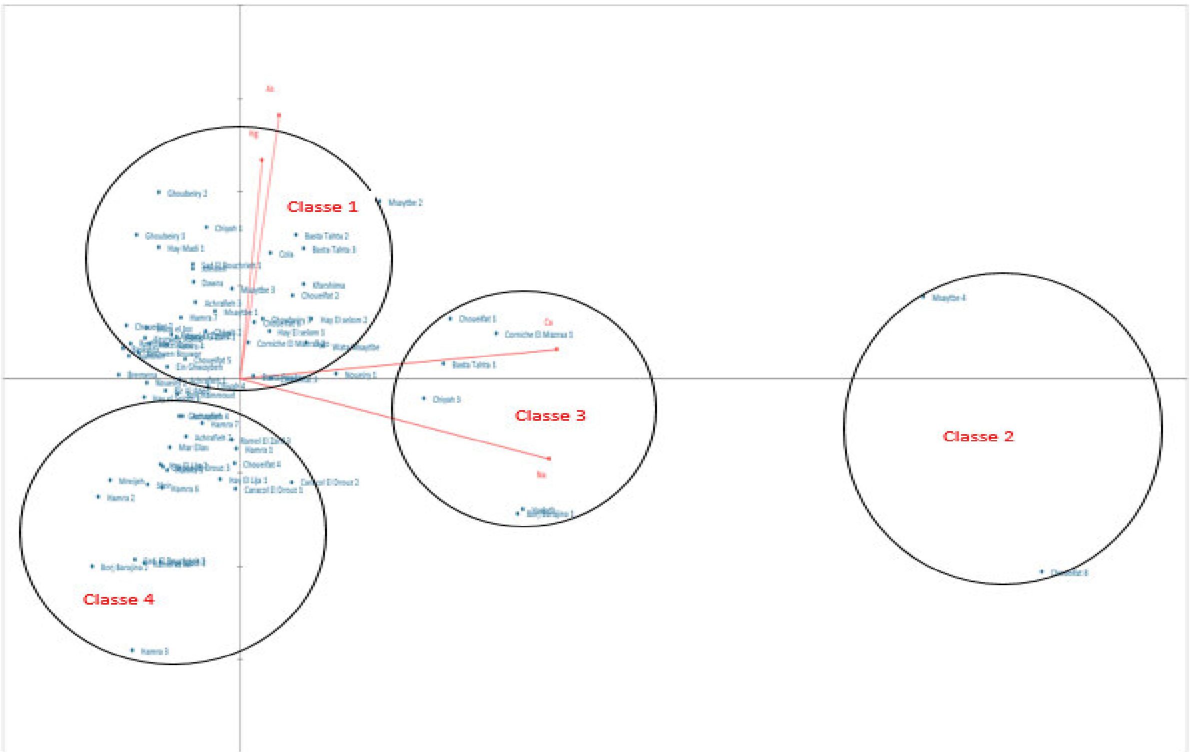

Figure 12. The Classes of individuals concerning the cations and heavy metals parameters.

Figure 13 shows the classes of individuals concerning the microbiological parameters. It can be noticed the following sequence:
• Class 1/4 (weight = 3, number = 3)
Class 1 is made up of 3 Sites (3.8% of sites), it is Chiyah 1, Chiyah 2 and Hamra 7, it is characterized by a high concentration of fecal Coliform and pseudomonas aeruginosa.
• Class 2/4 (weight = 1, number = 1)
Class 2 consists of 1 Site (1.26% of sites), and it is Borj Al Barajina 2, it is characterized by the extremely high focus on total coliform.
• Class 3/4 (weight = 1, number = 1)
Class 3 consists of 1 Site (1.26% of sites), and it is Dawra, it is characterized by a high focus on Ecoli.
• Class 4/4 (weight = 1, number = 1)
Class 4 is formed by 74 Sites (93.67% of sites), it is characterized by the low concentration of all the characteristics.

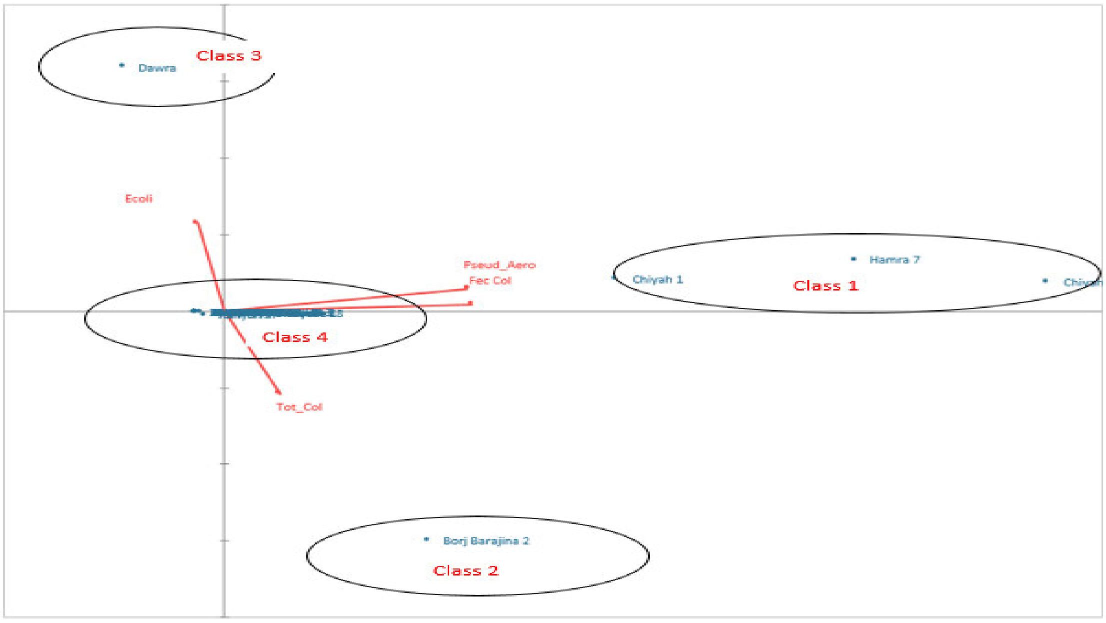

Figure 13. The classes of individuals concerning the microbiological parameters.

4. Conclusion

The study of drinking water of Beirut and Mount Lebanon reveals that sites in class 1 have high concentrations of Mercury and Arsenic. Analysis of the water quality shows that several locations, including Ashrafieh 3, Jdaydeh, Cola, Dawra, Sad el Bouchrieh 1, Msaytbeh, and Ghoubeiry 1, 2, have elevated mercury levels due to laboratories and hospital waste. Residents in these areas exposed to mercury may suffer from various neurological and behavioral issues, such as tremors, sleeplessness, memory loss, neuromuscular effects, migraines, and motor and cognitive dysfunctions.

The high concentration of calcium in the water is attributed to the presence of carbonate rocks like limestone and dolomite, which increase water hardness. In normal concentrations, calcium is beneficial for the body, but excessive levels can alter the water's taste and promote scale buildup in household appliances. On the other hand, arsenic levels in water need to be reduced or eliminated to meet acceptable standards. However, achieving this goal requires adequate funding and the implementation of appropriate technologies.

The examined water samples were found to be hazardous due to elevated levels of Pseudomonas aeruginosa, E. coli, total coliform, and fecal coliform. Most of the tested water samples exceeded normal bacterial levels. The consequences of this pollution are evident in the high cancer rate in Lebanon, partly due to the presence of heavy metals. Moreover, pollution-related health issues, including intestinal cancers, are prevalent due to air and water contamination. Bacteria, viruses, protozoa, and parasitic worms present in sewage and poor-quality drinking water contribute to various diseases such as diarrhea, dysentery, and gastroenteritis. Hepatitis A and typhoid are also affecting many patients due to water contamination.

In light of these findings, urgent and serious actions are needed to utilize, conserve, and protect water resources in Lebanon. This necessitates the implementation of more comprehensive national management plans and collaborations, as well as updating existing ones. Environmental laws and regulations should be strictly enforced, including increased taxes and penalties. Emphasizing sustainable development pillars in decision-making is crucial to protect and manage water resources while reducing their negative impact. It is essential to utilize all necessary national and international resources and consider the environment, especially water resources, in political decision-making.

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