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Environmental Assessment and Legal Approach of Qaraoun Artificial Lake, Lebanon

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Authors' contributions

This work was accomplished at the Lebanese University- Faculty of Agricultural Engineering and Veterinary Sciences- as a thesis prepared in order to obtain master degree in Environmental Engineering and natural resources. In this work, the authors study water quality parameters of the Qaraoun artificial Lake with legislations and policies.

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ABSTRACT

The Qaraoun artificial Lake, being one of the biggest water resources in Lebanon, is subject to pollution from different sources. The Qaraoun artificial Lake has recently become a wastewater collector from the river upstream. Human activities that exist near the lake exaggerate the problem.
In addition to analysis of water and field verification, modern techniques of remote sensing and statistical study were applied to facilitate identification of the main pollutants governing the lake water, and comparing the results of each parameters with the international and national guidelines for drinking water to induce the anomalous values in this study.
The study looks to the Qaraoun artificial Lake as one part, for this reason physico-chemical, organic chemical and inorganic non-metallic samples were collected monthly between 2007 and 2012 from the same site of the lake, and analyzed in order to determine water quality and the correlation between each parameter.

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Moreover there is no effect of year between 2007 and 2012 for all parameters except for nitrates and sulfates that makes respectively 2011 and 2008 two special years, therefore we studied the month effect of all parameters that shows: ammonia, nitrites, dissolved oxygen, phosphates and pH are not within the recommended guidelines suggested by LIBNOR, EU and WHO.
A legal approach was conducted to put adopted recommendations. The solution will be in the application of the environmental laws in general and the promulgation of environmental decrees in particular, because these decrees are still in their embryonic stage.

Keywords: Litani River; legislations; pollution; water quality parameters; anthropogenic interference.

1. INTRODUCTION

Water is life! From the first single cell organism to the most complex organism, we are all made of water. From the very primitive human gathering to the biggest city in our modern world, we survive on water. In a few words, we own our very existence to water.

The water crisis started after the industrial revolution of the 19th and 20th century. Due to demographic explosion, improvement of life style, increasing use of water for agricultural needs. Human beings not only begin over exploitation of the water resources but also started polluting water with a fast emerging industry and with waste water from the expanding human agglomerations. Moreover, human activities like agriculture, industries, sanitary landfills and septic tanks have caused severe water pollution.

The pressure on water goes in two very interdependent axis affecting quantity and quality, therefore it is a major global environmental concern and one of the leading worldwide causes of deaths and diseases. Around 20% of the world's population has no source of safe drinking water [1].

The quest for potable water has always been a priority for human civilization, and where water was found, life was found.

The world's awareness of the importance of water availability and quality issue has led to the creation of several international organizations, non-governmental organization, conferences, and cooperation between countries, in order to be able to study the water quality.

These organizations tried to develop strategies based on the idea that water is a finite and vulnerable resource that should be preserved and that water has an economic value as well as a social value. The added economic value to water is an attempt to give value to this resource and to facilitate its management and allocation, to assure the water security for undeveloped countries and the sustainability of this vital product.

The whole region, including Lebanon is witnessing a drastic climate change that is leading to significant drought over the coming years. Moreover, water quality deterioration has reduced the effective availability of fresh water for drinking as well as for irrigation [2].

Lebanon, the country which was described as the "Water Tower of the Middle East" has shifted within a couple of decades to a country under water-stress [3].

Water is one of the most precious resources in Lebanon. Unsustainable water management practices, increasing water demand from all sectors, water pollution, and ineffective water governance are key challenges facing Lebanon's water sector.

The driving forces affecting the quality and quantity of water resources in Lebanon are population growth and age structure, urbanization, economic growth and, more recently, climate change.

Water quality in Lebanon is a crucial and alarming issue that deserves attention since most of the water sources in Lebanon are contaminated, notably the surface water sources. It is about to become major problem if the situation in Lebanon remains as such. It is not exaggeration to say that more than 50% of the Lebanese water is contaminated [4].

Water quality is an issue that affects various sectors especially public health and economy. For instance, the deterioration of water quality in the Litani River watershed in Lebanon has caused the apparition of a total of 6.147 cases of diarrhea and typhoid (including paratyphoid) recorded during 2004, with 80 percent diarrhea cases. The majority of the cases were recorded near large communities and their distribution is consistent with the pattern of greater levels of pollution detected near these communities, which are predominantly associated with the discharge of untreated wastewater in the river [5]. The impact of poor water quality in any region is not limited to health only, but goes beyond that to having high economic costs from illness treatment, to water treatment, to the limitations of the exploitation of this water in the different economical sectors. For this reason, strict legislations and guidelines were set by governments and United Nations Organization on the quality of water needed in its different usages. The tracking of pollution in water and the quality of consumed water became the subject of numerous researches in all countries all around the world. Even more, detailed analysis of each type of major pollutants or chemical substances that might be present in water is undertaken to understand the origin of these chemicals and their effect on living creatures.

Rivers are the most important surface water resources used for different human domestic, agricultural and industrial purposes. Hence, it is important to have reliable information on trends of water quality for effective water management approaches [6].

The Litani River Basin (LRB) can is divided into two major hydrologic units. These are the upper and lower units which are separated by the artificial lake of Qaraoun [7-9].

The Qaraoun artificial Lake, being one of the biggest water resources in Lebanon, is subject to pollution from different sources. The location of Qaraoun artificial Lake is particularly fit to collect water from the river upstream; these waters are highly polluted. The lake has recently become a wastewater collector. Human activities that exist near the lake exacerbate the problem. Sedimentation and biodegradation are phenomenon taking place in the lake, leading to improvement in the water quality [10].

The main sources of water pollution in Qaraoun artificial Lake are attributed to:

1. Industry: where a total of 28 industries were surveyed in the Qaraoun zone. Major products are: rock cutting products, sponges, wooden products, concrete products and asphalt; cooled and packed fruits and vegetables, Arabic sweets, arak, wine, corn flakes, dairy products, bakery products, noodles, spaghetti, sugar products, chewing gum, and olive oil. Rock cutting facilities are concentrated on the eastern bank of the Qaraoun artificial Lake. The total estimated daily flow from these industries in the Qaraoun zone is calculated at 555 m^3/day of effluents that are mainly of the organic, biodegradable nature.
2. Non-industrial solid wastes and wastewater are a primary factor in freshwater, sea water and soil pollution. Wastes brought by wastewater conveyors are poured directly into the river shore without any treatment. Of the operational dumps, some are very close to the Litani and contribute to its pollution (less than 200 m), while others are relatively far and their direct impact is nearly negligible.
3. Agriculture: The most important constituents of agricultural runoff and water seepage are agricultural chemicals and non-degradable pesticides which end up in waterways with irrigation overflows. Two aspects of agricultural pollution were investigated: pesticides' and fertilizers' use.

The Lebanese famer lacks knowledge about pests, pesticides and alternative pest management techniques which are the main factors contributing to pesticide misuse. The prices of pesticides are a concern where older generic products are flooding the Lebanese markets because they are cheaper than their more modern replacements, but at the same time these older products pose a risk [11].

In addition, Global warming will affect precipitation. This will be reflected in changes to "freshwater availability and quality, surface water runoff and groundwater recharge" [12].

There is an urgent need for water management plan in the Qaraoun artificial Lake, because the problem of water in the study area is not water availability; it is a problem of water management. This approach treat the water problem in an integrated manner, this means that all users of water are interdependent and should be implemented in water management and in the decision making.

This study aims not only to analyze water quality of the Qaraoun artificial Lake with quantifying the level of pollution by measuring the necessary parameters but also to identify pollutant sources and legal protection of lake water with related laws. In addition to analysis of water and field verification, modern techniques of remote sensing and statistical study were applied to facilitate identification of the main elements governing pollutant of lake water to determine the effect of year and month for each parameter between 2007 and 2012, and comparing the results of each parameters with the guideline of MoE decree 52/1, to induce the anomalous values in this study, and consider readings as anomalous if they are over/ below the level of multipurpose usage according to the international (WHO and EU) and national (LIBNOR) in order to show the anomalous reading with respect to each parameter.

Recently, the number of studies applied to the Lebanese rivers has increased, but all of them focused on the pollution aspects rather than the relationship between pollution and legal state. The study presented in this thesis is the first one concerning such a relationship for the Qaraoun artificial Lake and legal approach.

This study seeks to show the complex interactions between the environmental assessment (physico-chemical study) and legislations and policies relevant, where the environmental problems frequently need legal issues whose resolution demands knowledge of law and the environment. Stressing on the importance of the application of the environmental impact assessment (EIA) for all establishments existing and planning to be constructed near the Litani River and Qaraoun artificial Lake to reduce water pollution. However, starting urgently the application of the principles of the environmental law 444/2002 such as prevention, precaution and polluter/payer principles, etc.

The difficulties encountered in this study were the insufficient of initial information about the environmental and legal status of the lake due to the small number of studies available and the absence of continuous data. In addition to the problem of data lacking, there was also a lack of cooperation from various specialized centers that have related data.

This study presents an environmental assessment and legal approach of the Qaraoun artificial Lake. It describes a general international and national overview on water. It highlights the pressures on water from industry, non-industrial solid wastes, wastewater and agriculture. On another hand a legal approach and responsibility is treated concerning the Qaraoun artificial Lake. Samples are taken from the area of study of the Qaraoun artificial Lake with the necessary materials and methods to analyze and study water quality parameters from January 2007 to May 2012. Then, results are discussed and analyzed physico-chemically and statistically (month effect, year effect, discriminant factorial analysis (AFD) and correlation) in order to put a conclusion and to propose potential remedial recommendations.

1.1 Study Area

This study treats to the Qaraoun artificial Lake as one part, for this reason this study takes the values of water samples from the same site of the lake, samples taken monthly from this site between January 2007 and May 2012 to analyze water quality parameters (Fig. 1).

The Qaraoun sampling coordinates are:

33º32'59.82"
5º41'01.76"

Fig. 1. Site location according to the Qaraoun sampling coordinates

The lake is an artificial (man-made) reservoir located in the southern region of the Beqaa Valley, Lebanon. It is bordered by the villages of Aitanit, Bab Maraa, Saghbine and Qaraoun. It is the largest body of freshwater in Lebanon (Fig. 2).

It was created near Qaraoun village in 1959 by building a 61-metre-high (200 ft) concrete-faced rockfill dam (the largest dam in Lebanon) in the middle reaches of the Litani River (longest river in Lebanon). The reservoir has been used for hydropower generation (190 megawatts or 250,000 horsepower), domestic water supply, and for irrigation of 27,500 hectares.

The annual surface water flow in the Litani River received at Qaraoun artificial Lake is 420 million cubic meters. This flow is used for generating hydroelectric power of 600 GWh at three hydroelectric power stations at Markaba, Awali and Jun with the total installed capacity of 190 megawatts (250,000 hp). During the dry season, 30 million cubic meters of water is diverted from Markaba power station to meet the needs of the Kassmieh irrigation project.

The lake is a habitat for some 20,000 migratory birds which visit it annually.

The Qaraoun dam at an elevation between 800 to 850 meters above sea-level (Fig. 3). The estimated area of this basin is approximately 1,400 km^2, with several perennial tributaries feeding the Litani River, mainly Berdawni, Ghzayel, Qib Elias, and Chtoura. The Qaraoun Reservoir can hold up to nearly 220 million cubic meters of water and an effective storage of 160 Mm^3 from year to year. It regulates the downstream flow of the Litani River for power generation and irrigation.

Surrounding the lake itself are woodland, orchards, and low-growing scrub. The water levels fluctuate severely in the course of the year and there is little or no submerged or emergent vegetation.

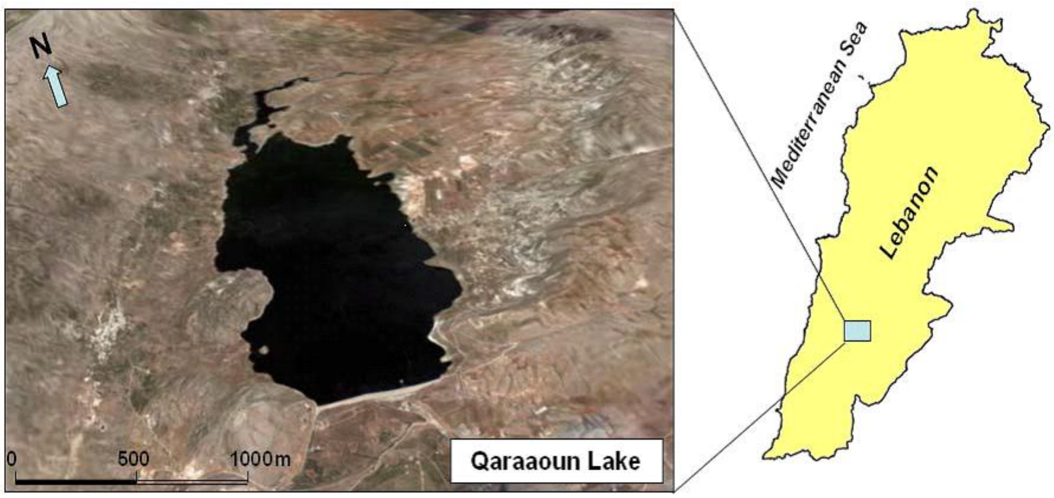

Fig. 2. Location map of Qaraoun artificial Lake (image adapted from Google Earth)
Central coordinates: 35°41.38' East 33°34.54' North.

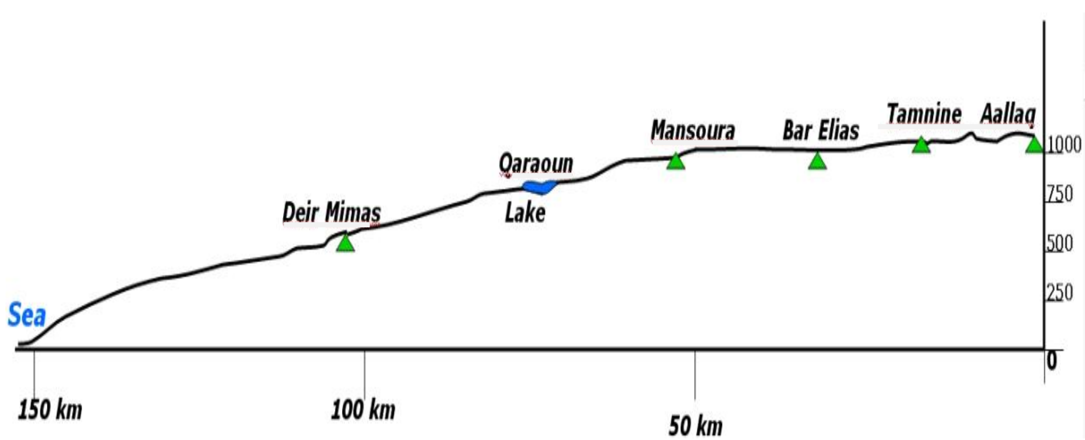

Fig. 3. Altitude profile of Qaraoun artificial Lake [10]

1.2 Land Use

From the satellite images (Landsat 7 ETM+), a number of land features were described and digital cartography was applied to produce a land use map (Fig. 4). The map covers the area surrounding the lake, and includes the catchment boundaries that drain to the lake.

The main terrain classes that may contribute pollutants were considered. These are urban and industrial sites, bare soil, and vegetation cover. Field reconnaissance verified the extracted information from the satellite images and reported obvious land uses on the lake. Within the area of the lake, the following land use percentages were found: 8% urban, 2% industrial, 39% bare rocks and soil (mostly alluvial deposits), 31% irrigated land and 20% non-irrigated land. In addition to land use, surface water channels were plotted on the map to show possible routes of pollutant transfer to the lake [13].

2. MATERIALS and METHODS

2.1 Data Collection and Preparation

Water samples were collected in polyethylene bottles, filtrated through a 0.45 μm filter, and stored at 4ºC. They were then analyzed spectrophotometrically with pertinent and certified reagents (LaMotte, USA). Finally, the results were evaluated in accordance to the Lebanese Standards Institution (LIBNOR), Standard for Drinking Water, the World Health Organization (WHO) Guidelines for Drinking Water Quality [14], European Union (EU) Guidelines.

2.2 Tools for Data Acquisition

In this study, the majority of data availability was dependent on records and measures from different sources. These sources are almost related to governmental sectors and institutes concerned with water resources and metrological conditions.

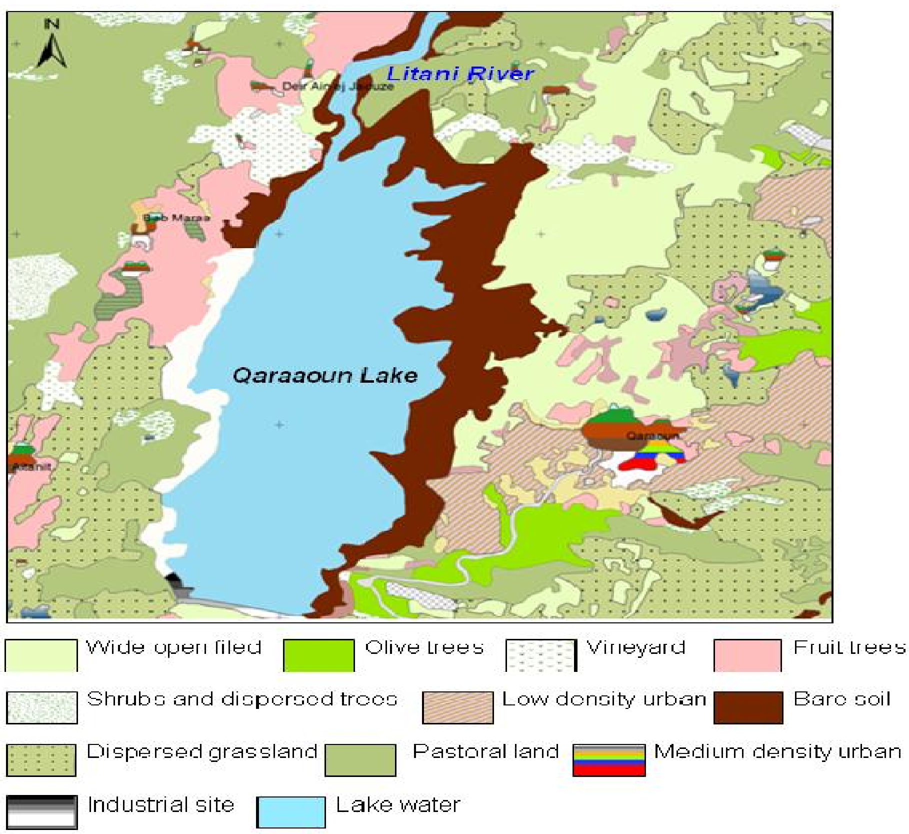

Fig. 4. Land use map of Qaraoun artificial Lake (extracted from satellite image Landsat 7 ETM+, 2003)

Accordingly, there are a big number of records of physico-chemical, hydrological and climatic data, which is adopted mainly from the Litani River Authority (LRA).

The data in this project was adopted using several methods. These methods include ordinary tools and methods and advanced techniques.

Four major phases were used in this study: In-situ physical investigation, laboratory testing, and satellite images analysis to assess land use in the area of study. All these phases were accompanied with field reconnaissance and verification, followed finally by a statistical study. Each phase is shown in (Fig. 5).

2.2.1 Ordinary tools and methods

The ordinary tools used include:

- Field investigation visits were done to the area of study and some information, field view and photos were taken.
- Visits to Governmental Sectors (Ministry of Environment, Ministry of Energy and Water, Ministry of Agriculture) to collect some data.
- Visits to the Ibrahim Abdel Aal association, ESCWA, Lebanese parliament.
- Rainfall gauges in several representative sites with a uniform geographic distribution to measure precipitation rate (Litani River Authority; from 2007 to 2012).
- Hydrographs and flow-meters on river to record water discharge measures (Litani River Authority; from 2007 to 2012).
- Lebanon's Atlas of Climate.

2.2.2 Advanced techniques

- The satellite images are Landsat 7 ETM+(30 m resolution). This task was conducted at the National Council for Scientific Research-Remote Sensing Center (CNRS) using ArcView software.
- Satellite image analysis was applied to identify land use around the lake and it is indicative of the sources of pollution surrounding the lake. Major features were digitized on screen, using ancillary data for the purpose of this study. All divisions of terrain elements were plotted and classified as follows: Vegetation cover of all types (e.g. fruit trees, shrubs, olive trees, etc.), urban and industrial sites, bare rocks and soil, in addition to soil and alluvial deposits.
- Using statistic software to do the statistical study (Stratigraph) for variance components; and (SPSS) for correlation and AFD "Discriminant Factorial Analysis".
- Using Microsoft Excel to show the variation of parameters and analyze the results.

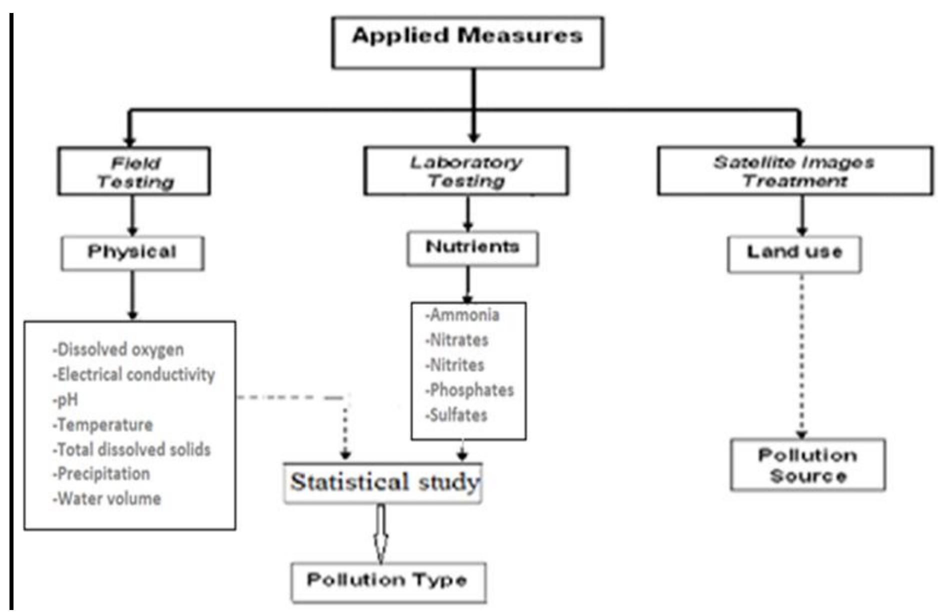

Fig. 5. Applied measures to identify pollution type and sources in Qaraoun artificial Lake

2.3 The Equipment Used in the Analysis

1. Colorimeter smart 2 (LaMotte, USA): to complete the analysis of the water at the site and to examine: ammonia, nitrates, nitrites, sulfates, and phosphates (Table 1).
2. Tester (LaMotte, USA): At site to check the electrical conductivity, total dissolved solids, temperature and pH.
3. Tracer (LaMotte, USA): At site to check dissolved oxygen.
4. Water volume, precipitation (Rainfall gauges and Hydrographs of Litani River Authority LRA).The data used to illustrate water quality parameters trends in this study is almost adapted from records taken from the Litani River Authority.

2.4 Water Quality Guidelines

The results obtained from the conducted experiments are to be compared to the guidelines to build up reasonable conclusions and recommendations.

Different measured values for all tested parameters were subjected to calculation, in order to have a unified unit to induce the anomalous values in this study; we considered readings as anomalous if they are over/below the level of multipurpose usage, according to the international and national guidelines (Table 2), in order to show the anomalous reading with respect to each parameter.

2.5 Legal Approach

This study seeks to provide the complex interactions between the environmental assessment (physico-chemical study) and legislations and policies relevant, where the environmental problems frequently need legal issues whose resolution demands knowledge of law and the environment, where this approach treat the water problem in an integrated manner, this means that all users of water are interdependent and should be implemented in water management and in the decision making.

The institutional framework for the water sector in Lebanon is characterized by a myriad of ministries, water establishments, public agencies, municipalities, etc. Key actors in the water sector often duplicate each other's work, few times they complement each other, always operating through weak links of communication and responsibility, which have led to a lack of policy focus, with no one institution taking the effective lead of the sector.

According to the legal framework, governing the water sector, there is no clear stipulated authority for the Ministry of Energy and Water (MoEW) or any agency or a public institution for the formulation and development of policies. The absence of a clear government policy which operates and regulates the water sector lead to a freeze in this sector for decades. To this day, there is only an initiative, limited so far, to define a clear policy for the water sector supported by legislations and regulations, the law 221/2000 and its amendments. This law defines the institutional foundation that the sector must proceed from but its impact is not yet significant.

Law 221/2000 was amended by Laws 241 (dated 7/08/2000) and 337 (dated 14/12/2001). These laws were promulgated to reform the water sector and clearly define the roles of MoEW and regional water establishments (RWEs), and the relationship governing them. The Law however does not explicitly grant MoEW or any other public institution the responsibility or power to set policy. The MoEW by its powers can formulate policy and provide policy advice to the Government of the day, but it does not have exclusive power of policy setting in the water sector. It should be noted that MoEW has to function in a legal environment that still has laws from the 19th and early 20th centuries in currency, where most of laws in Lebanon were formulated by the Ottoman Empire and modified and used by the French Mandate. The first law declaring water resources as a public property, aside from established water rights, the Decree 144 was issued in 10 June 1925. In 1926, the French Mandate introduced a new law, the Decree 320 of 26 May 1926, which refers to the organization and describes "Water Rights" for individual water owners. In 1930, the Government of Lebanon issued a decree, which considers that all water in privately owned land is the property of the landowner and is privately owned, thus changing what was stipulated in the previous laws. Another remaining law of March 1918 relates to the arrangement and the renovation of common irrigation canals.

Table 1. Analyzed parameters, test method, range and detection limit (LaMotte, USA)

Test factor	Test method (of reagents)	Range (PPM)	Detection limit (PPM)
Ammonia Nitrogen	Nessler	0-5.00	0.05
Nitrates Nitrogen	Cadmium Reduction	0-3.00	0.05
Phosphates	Ascorbic Acid	0-3.00	0.07
Sulfates	Barium Chloride	0-100.0	1.0

Table 2. Comparison of various drinking water guidelines [15]

Parameters	LIBNOR	EU standards	WHO standards
pH	6.5–8.5	6.5–9.0	No guideline
Total Dissolved Solids (mg/L)	500	No guideline	No guideline
Electrical Conductivity (μS/cm at 20ºC)	No guideline	2.500	No guideline
Dissolved Oxygen (mg/L)	No guideline	No guideline	No guideline
Ammonia (mg/L)	No guideline	0.5	No guideline
Nitrates (mg/L)	45	50	50
Nitrites (mg/L)	0.05	0.5	3.0
Phosphates (mg/L)	1.35	No guideline	5.0
Sulphates (mg/L)	250	250	500

They constitute the fundamental texts governing water in Lebanon. They have undergone minor amendments since then, although their original underlying principles have not been altered. A large number of concessions and water committees have been created in the few decades before and after the end of the French Mandate over Lebanon. Since 1951 the government of Lebanon issued some 22 decrees dealing with the creation of water authorities in the country [16].

When the cabinet approves the National Strategy for Water Sector prepared by the Ministry of Energy and Water, many of the outstanding problems will find its route to be solved. Through the management of this sector in a rational and raising awareness about environmental problems and approve the implementation of initiatives launched recently (for example water law and decimal plan of the Ministry of Energy and Water and program of the Council for Development and Reconstruction of sewage), the national strategy of the water sector will be able to mitigate and perhaps eliminate duplication and overlap of work between institutions and the lack of efficiency in the water sector.

Unfortunately, our laws move so slowly towards development and to be applicable in all the country stilling just like words on paper. On another hand, The MoE has no authority to resolve all issues relating to the environment due to the crossing roles between different ministries.

There is common recognition in Lebanon that environmental protection requires a collaborative and concerted effort at all levels. Working within the framework of an evolving legal and regulatory framework, government agencies at national and local levels are becoming more aware of the need to consider the environmental impacts of their policies and actions, and are gradually building their capacity to manage the environment.

Law 444/2002 has two very important decrees: decree 8157 in 2012 about the formation of the National Council for the Environment and define its functions and organization also the decree 8633 in 2012 about assets of EIA (Environmental Impact Assessment).

The Environmental Council would be charged with formulating proposals and recommendations for a comprehensive and integrated environmental policy as well as suggesting implementation plans, which would become binding upon their approval by the Council of Ministers. Membership of the National Environmental Council is to be evenly divided among representatives of concerned ministries and those of civil society (NGOs, private sector, academia).

Currently, a number of laws, decrees, and ministerial decisions govern environmental management in Lebanon. However, there is lack of clarity and internal inconsistencies in legal and regulatory texts. Moreover, enforcement remains a major weakness of the environmental control system. Deficient enforcement is sometimes, but not always due to institutional weaknesses, special interests, and political interference that stand in the way of effective enforcement.

At the legislative level, water sector suffers from duplication of the work of some main institutions in the water sector. The work of institutions and key actors in the sector occurs in the absence of vigorous coordination with each other and the lack of clarity of the responsibilities, this will lead to the formulation of un-purposeful and unclear policies, it also leads to a lack of visibility of a leading institution in the sector.

The legislation relating to environmental issues and issued since a short time, responded to more than one target, and decide more than one demand and need, but it is not really valid at the time of changes and where the mentality of the citizen changed with him, the nature of land and ways of life, especially with the technological development and its different effects on environment.

Also, the scattering, plentiful and complexity of environmental texts without being collected in front of a basic title to be able to develop a uniform vision of environmental law and determine environmental policies applied and the plan the way intended by the legislature to protect the environment, in light of the possible existence of conflicting or heterogeneous texts to some extent disrupts the role and effectiveness of the law.

The creation of the High Council for water is a major step to coordinate of decision making activities, sharing knowledge and exchange of experience. Its role will be decisive on updating and adjusting of Water National Master Plan.

The development and implementation of program for strengthening national capacities in water quality management including water resources management, wastewater management, operation and maintenance of treatment plants, wastewater reuse, database creation and updating, information dissemination, community participation, monitoring and enforcement, and new economic measures such as “Polluter Pays”. Strengthen management in order to develop more efficient use of limited financial resources, and the application of principles environmental laws such as prevention, precaution, etc.
The solution is in the application of the laws, as the environmental policies remain a dead ink on paper if it is not really implemented on the ground. It is worth thinking about raising environmental education citizen to respect the environment, on the other hand requires the development of mechanisms of control, accountability and strengthens of its bodies so as to ensure the application of policy of reward and punishment.

Finally, as for the Arab world in general, Lebanon will have to face the following challenges:

- The lack of public awareness of rational use and management of water.
- The lack of institutional coordination, relevant legislation and implementation, and inadequate financial resources.
- The lack of up-to-date knowledge of sources in quantity and quality.
- The absence of cooperation at the regional or sub-regional level in shared rivers.
- The lack of decrees of application of Law 444/2002 for the protection of the environment.

3. RESULTS AND DISCUSSION

In the following section the obtained data will be represented, analyzed and assessed for each parameter.

3.1 Variance Components Analysis

The variance components analysis of water quality parameters of samples studied of Qaraoun artificial Lake between 2007 and 2012, of factors (month and year) with 5% for signification level shows the variation of water quality parameters of monthly samples studied of Qaraoun artificial Lake from January 2007 to May 2012.

It shows that the factor contributing the most variance is month for all water quality parameters, and shows that there is no effect of year between 2007 and 2012 for all parameters except for nitrates and sulfates.

We consider the percent of contribution of the total variation from (75%) to (100%) to indicate that the factor contributing the most variance is month.
So, the nitrate’s month percent is (68.2079%) and the sulfate’s month percent is (72.9014%), moreover we contributed the factor of year to nitrates and sulfates from 2007 to 2012. The

variation in year is observed for nitrates (32%) of total variation and for sulfates (27%) of total variation.

3.1.1 Month effect

Based in median not in mean because it didn't take care about extremities but it takes the range of (50%) where result exist, and it takes (25%) up and (25%) down of the median. Specifically, every value is out of the box plot (called outside or far out values) counted like a false value or reading error.

The effect of month will be studied below for all water quality parameters of samples studied of Qaraoun artificial Lake from January 2007 to May 2012.

3.1.1.1 Physico-chemical parameters

3.1.1.1.1 Electrical Conductivity

(Fig. 6) shows the changes of electrical conductivities values from January to December from 2007 to 2012. The electrical conductivity values are between 290 and 510 µS/cm.

The EC value in January is (290-495 µS/cm), this EC value increases to reach maximum value in February (475-510 µS/cm), then it decreases to obtain (470-505 µS/cm) in March, this EC value increases to obtain (440-508 µS/cm) in April, then it decreases progressively to reach minimum in August (290-340 µS/cm), then it increases to obtain (370-430 µS/cm) in December. It is apparent that electrical conductivity values for all months do not exceed 510 µS/cm.

The EC still within the MoE standard (1000 µS/cm) and the EU standards for drinking water (Table 2).A significant increase in EC indicates that pollution discharges have entered the water. The EC for ideal fresh water streams should be between 150 and 500 µS/cm to support diverse aquatic life. So, we can conclude that the quantity of inorganic dissolved solid is not high to increase EC over than guidelines.

Electrical conductivity (EC) increases naturally from upstream to downstream due to the dissolution of bedrock. Values usually range between 200 µS/cm to 400 µS/cm [17- 18- 19- 20- 21- 22]. In the presence of large terrigeneous inputs (leaching from agricultural soils, domestic and industrial effluents) it reaches 800 µS/cm.

So, Qaraoun' EC value reflect leaching from agricultural soils, domestic and industrial effluents. It's noted that TDS usually ranges between 0.5 and 1 time the EC.

3.1.1.1.2 Hydrogen potential pH

(Fig. 7) shows the changes of pH values from January to December from 2007 to 2012. The pH values of water are between 7.5 and 8.65.

The pH value is (7.7-8.3) in January, this value decreases to obtain (7.5-8.1) in February, then it increases progressively until it reaches its maximum (8.6-8.65) in May, then it decreases to obtain (8.1-8.4) in June, this value increases to obtain (8.4-8.6) in August, then it decreases to obtain (7.8-8.2) in September, then it increases progressively (8.19-8.4) in November, finally it decreases to obtain (8-8.2) in December.

It is noteworthy to mention that pH of the Qaraoun Reservoir over the year has been between 7.5 and 8.65. Compared to LIBNOR guidelines for drinking water, the pH values were within normal limits all months except in May, July and August, it reaches the maximum in May and July (Table 2). Its values were within the recommended range (6.5-9) suggested by EU (Table 2). So, pH values tend to be basic (>7) and are at acceptable levels. This is indicative of effluent sources of water to the lake.

Expected impact of pollution: When pollution results in higher productivity (e.g., from increased temperature or excess nutrients), pH levels increase, as allowed by the buffering capacity of the lake. Although these small changes in pH are not likely to have a direct impact on aquatic life, they greatly influence the availability and solubility of all chemical forms in the lake and may aggravate nutrient problems. For example, a change in pH may increase the solubility of phosphorus, making it more available for plant growth and resulting in a greater long-term demand for dissolved oxygen.

3.1.1.1.3 Total dissolved solids

(Fig. 8) shows the changes of total dissolved solids concentration from January to December from 2007 to 2012. The concentration of TDS is between 205 and 359 mg/L.

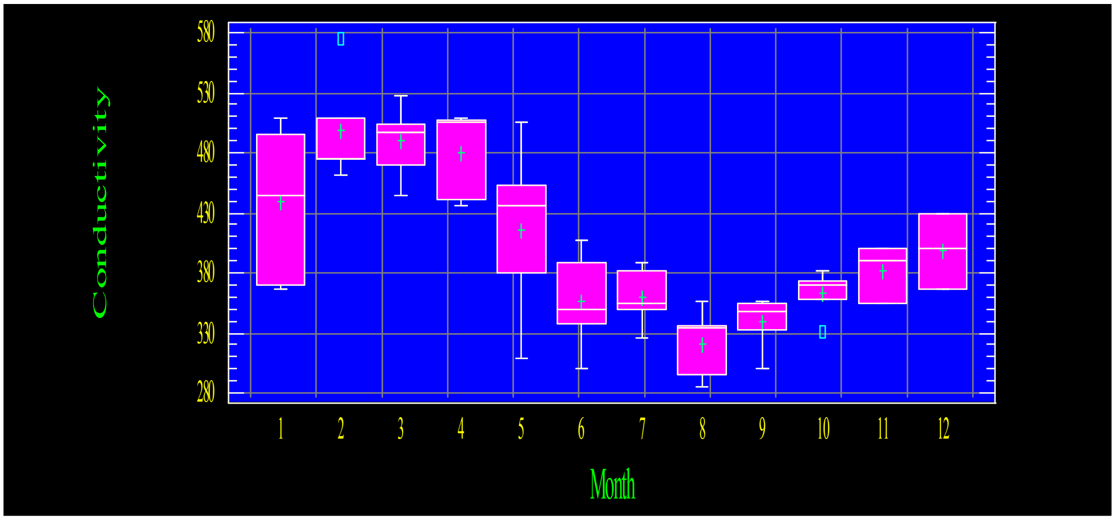

Fig. 6. Electrical conductivity values from January to December from 2007 to 2012

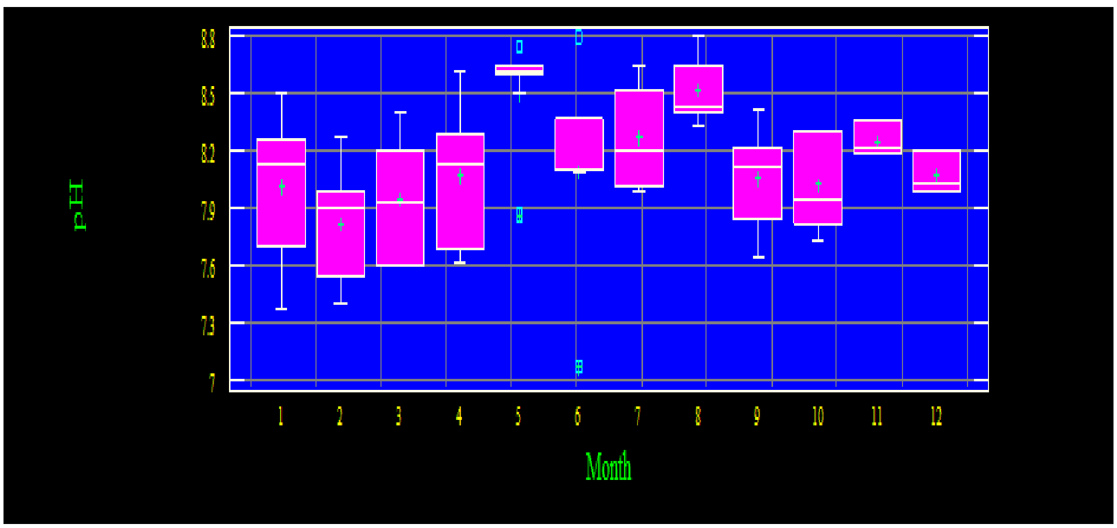

Fig. 7. pH values from January to December from 2007 to 2012

The concentration of total dissolved solids is (270-348 mg/L) in January, this concentration increases progressively to reaches its maximum (300-359 mg/L) in April, then it decreases progressively until it reaches its minimum (205-235 mg/L) in August, finally it increases to obtain (258-298 mg/L) in December.

The concentration of TDS is in the normal range (205 and 359 mg/L), it is within the drinking water guidelines given by LIBNOR, EU and WHO (Table 2), his range is acceptable for human consumption as well as irrigation purposes, its values was within the drinking water guidelines given by LIBNOR, EU and WHO.

Total Dissolved Solids (TDS) values fluctuate between a minimum of 150 mg/L for the less polluted waters and a maximum of 600 mg/L for those that are subjected to domestic and industrial discharges [24- 25]. It's noted that TDS usually ranges between 0.5 and 1 time the EC.

3.1.1.2 Physical Parameters

3.1.1.2.1 Precipitation

(Fig. 9) shows the changes of precipitation volume from January to December from 2007 to 2012. The volume of precipitation is between 0 and 210 mm.

The volume of precipitation is maximum (50-210 mm) in January, this volume decreases until it reaches its minimum (0 mm) in June and it still (0 mm) in August, then it increases progressively to obtain (40-160 mm) in December.

Precipitation occurs on 80 to 90 days a year, mainly between October and April. About (75%) of the annual stream flow occurs in the five month period from January to May, (16%) from June to July and only (9%) in the remaining five months from August to December.

3.1.1.2.2 Temperature

(Fig. 10) shows the changes of temperature values from January to December from 2007 to 2012. The temperature is between (7-27.5ºC).

The temperature is (7-9ºC) in January and it is the minimum value, this value increases until it reaches its maximum (26-27.5ºC) in august, then it decreases to obtain (9-10.5ºC) in December.

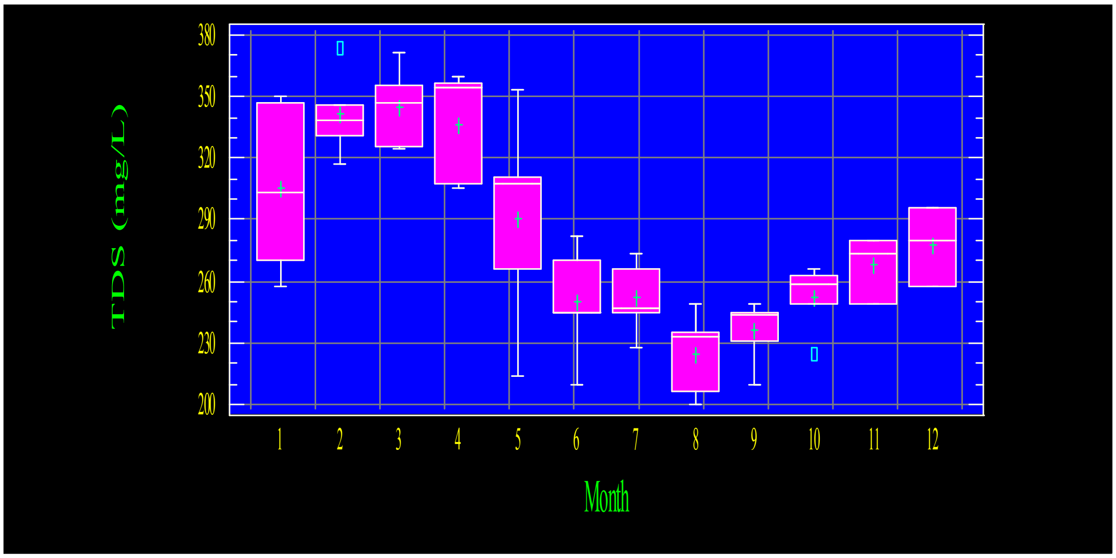

Fig. 8. Concentrations of TDS from January to December from 2007 to 2012

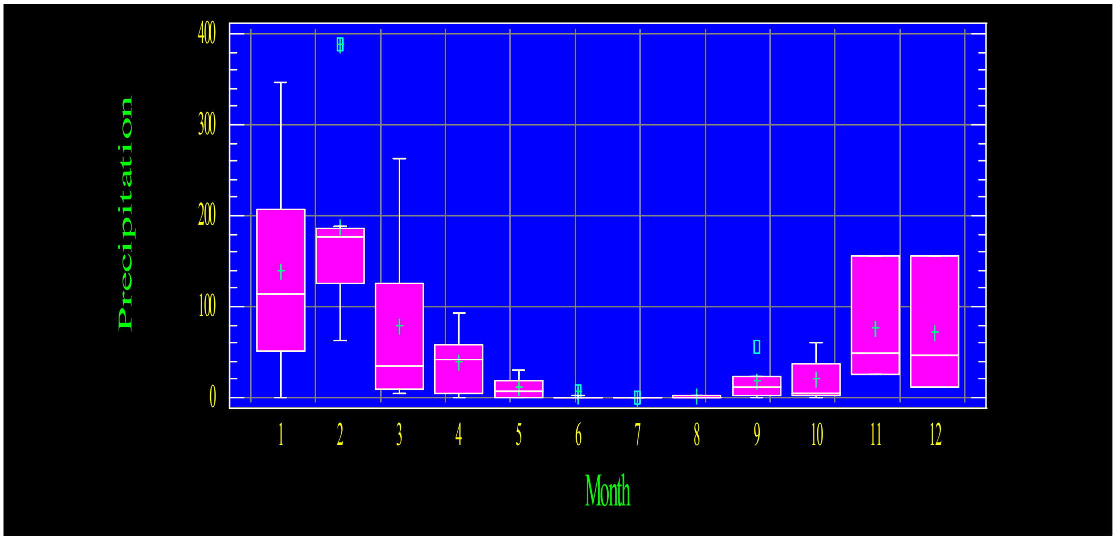

Fig. 9. Volume of precipitation from January to December from 2007 to 2012

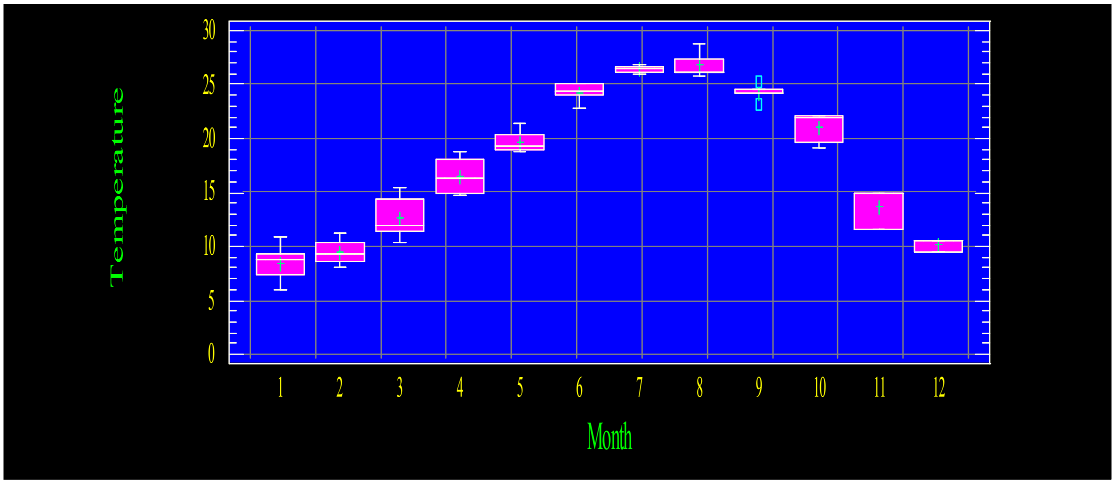

Fig. 10. Temperature values from January to December from 2007 to 2012

The temperature limits weren't determined since the type of fish living in the lake is not identified and it depends on geography conditions.

So the temperature increases from January to August and decreases from August to December.

The water temperature varies in time and in space and is related to the ambient air temperature. Generally it increases from upstream to downstream and during the dry summer seasons [23].

Urban effluents normally increase the temperature of receiving waters particularity during warmer months.

3.1.1.2.3 Water volume

(Fig. 11) shows the changes of water volume from January to December from 2007 to 2012. The water volume is between 40 and 210.5 Mm^3.

The water volume of the Qaraoun artificial Lake is (40.2-40.6 Mm^3) in January, this volume increases until it reaches maximum (180-210.5 Mm^3) in April, then it decreases until it reaches its minimum (40-40.5 Mm^3) in December.

So, water volume has high value between January and April due to the rain and the melting of snow and much lower during the dry period between May and November, this is conform to the discussion of Khalaf et al., 2007.

3.1.1.3 Inorganic Non-Metallic Chemical Parameters

3.1.1.3.1 Ammonia

(Fig. 12) shows the changes of ammonia concentration from January to December from 2007 to 2012. The concentration of ammonia was between 0.09 and 1.32 mg/L.

The concentration of ammonia is (0.78-1.3 mg/L) in January, this concentration increases until it reaches its maximum (1.32 mg/L) in February, then it decreases progressively to obtain (0.09-0.2 mg/L) in June, then it increases quickly to obtain (0.25-0.72 mg/L) in July, this concentration decreases quickly until it reaches its minimum in August (0.09-0.19 mg/L), and finally it increases progressively to obtain (0.82-1.22 mg/L) in December.

In any case, the concentration of ammonia exceeds EU guidelines (0.5 mg/L) from November (0.55-0.8 mg/L) to April (0.55-0.65 mg/L) (Table 2), this fluctuation in concentration is due to variation of industrial and agricultural activities.

This is absolutely due to the disposal of fecal waste (human and animal) in water. Ammonia (NH_3 or NH_4^+) contamination is usually an indicator of sewage pollution which most certainly applies to Lebanon for its lack of a national wastewater treatment system. Ammonia is rapidly oxidized in natural water systems by special bacterial groups that produce nitrites and nitrates. This oxidation requires that dissolved oxygen be available in the water.

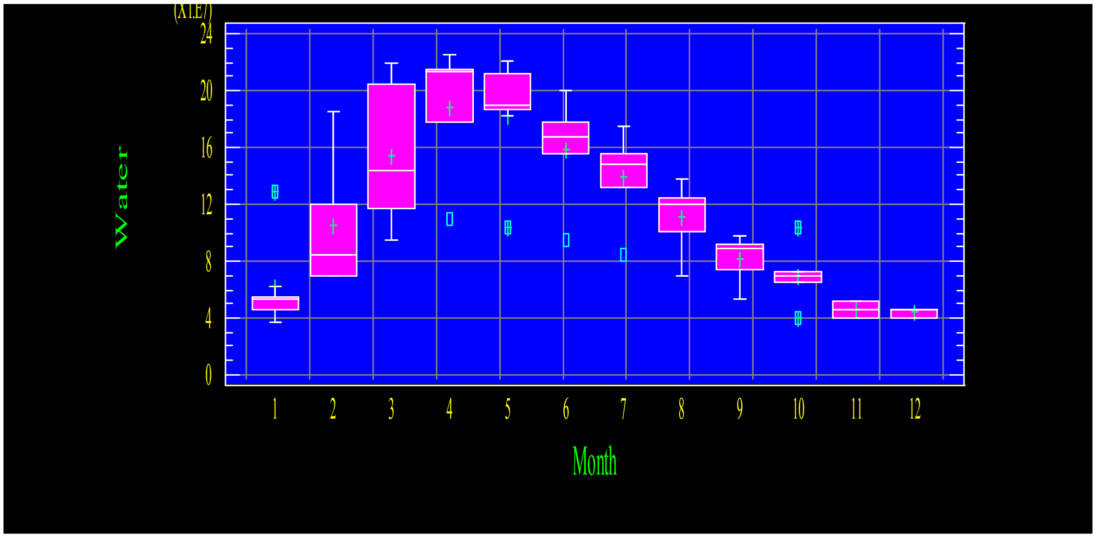

Fig. 11. Concentrations of water volume from January to December from 2007 to 2012

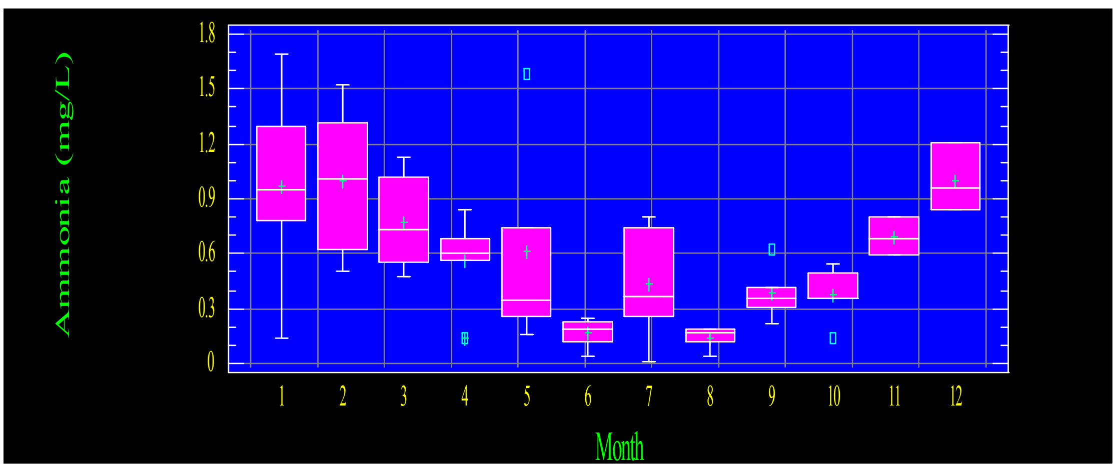

Fig. 12. Concentrations of ammonia from January to December from 2007 to 2012

The concentrations of ammonia that were found exceeding recommended guideline of drinking water are indicative of municipal wastewater discharges, and some industrial charges especially the agrofood industries, this result is conform with “the Business Plan for Combating Pollution of the Qaraoun Lake” conducted by ELARD 2011 saying that the lake waters may not be able to maintain a healthy medium for aquatic life due to high ammonia levels. Additional concerns are reported for ammonia which is also toxic to fish.

3.1.1.3.2 Nitrates

(Fig. 13) shows the changes of nitrates concentration from January to December from 2007 to 2012. The concentration of nitrates is between 4 and 22 mg/L.

The concentration of nitrates in January is (6-14 mg/L), this concentration increases progressively to reach maximum (11-22 mg/L) in April, then it decreases progressively to obtain (13-16 mg/L) in May, this concentration increases progressively to obtain (14-19 mg/L) in July, then it decreases progressively to obtain (7-11 mg/L) in September, then it increases progressively to obtain (4-17 mg/L) in November, finally it decreases to obtain (6-15 mg/L).

Nitrates are considered to be very mobile due to its solubility and anionic form, moving long distances in water without transformation.

Normally, guidelines from around the world limit the acceptable amount of nitrates in drinking water to about 44 mg/L. The concentrations found for nitrates (4 and 22mg/L) are acceptable. They don't exceed drinking water guidelines given by LIBNOR (45 mg/L), EU (50 mg/L) and WHO (50 mg/L) (Table 2).

This could be related to the excessive release of nitrates enhanced eutrophication and lead to the formation of algal blooms along the lake, thus, the denitrification cause a decrease in the nitrates.

An increase of levels of nitrates in samples during the summer ascertained the impact of current agricultural practices on water quality and the importance of extension programs to insure proper application of fertilizers.

3.1.1.3.3 Nitrites

(Fig. 14) shows the changes of nitrites concentration from January to December from 2007 to 2012. The concentration of nitrites over time was between (0.2-0.9 mg/L).

The concentration of nitrites in January is (0.55-0.8 mg/L), this concentration decreases to obtain (0.3-0.6 mg/L) in February, then it increases to obtain (0.52-0.7 mg/L) in march, then it decreases to obtain (0.5-0.6 mg/L) in April, this concentration increases to obtain (0.4-0.7 mg/L) in May, then it decreases progressively (0.25-0.3 mg/L) in September and it reaches its minimum in August (0.2 mg/L), finally this concentration increases until it reaches its maximum (0.4-0.9 mg/L) in December.

Its values were higher than the drinking water guidelines given by LIBNOR (0.05 mg/L) and exceeded it in all months, and it exceeds EU (0.5 mg/L) from November to May, but it WHO guideline (3 mg/L) (Table 2), this fluctuation in concentration is due to variation of industrial activities.

The concentrations of nitrites that were found exceeding recommended guideline of drinking water are indicative of municipal wastewater discharges, and some industrial charges especially the agro food industries, this result is in conformity with the business plan for Combating Pollution of the Qaraoun Lake conducted by ELARD 2011.

Also the presence of nitrites in water is attributed to denitrifying bacteria occurring in anaerobic conditions.

3.1.1.3.4 Phosphates

Fig. 15 shows the changes of phosphates concentration from January to December from 2007 to 2012. The concentration of phosphates is between 0 and 1.5 mg/L.

The concentration of phosphates in January is (1.1 mg/L), to this concentration increases to obtain (0.7-1.5 mg/L) in February, then it decreases to obtain (0.8-1 mg/L) in march,

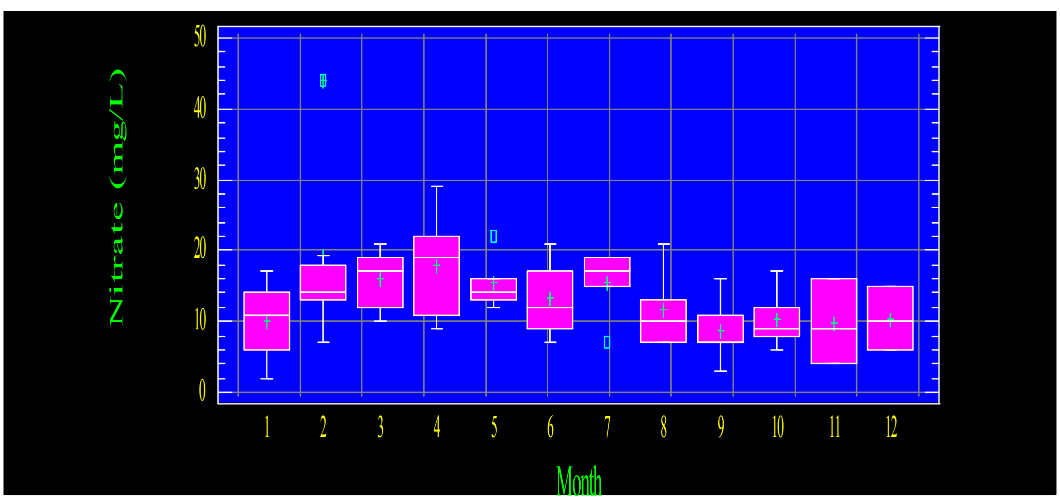

Fig. 13. Concentrations of nitrates from January to December from 2007 to 2012

this concentration increases to obtain (0.3-1.2 mg/L) in April, then it decreases until it reaches its minimum (0 mg/L) in June, this concentration increases to obtain (0-1 mg/L) in July, then it decreases to obtain (0-0.7 mg/L) in September, finally it increases progressively to reaches its maximum (0-1.5 mg/L) in December.

The phosphates didn't exceed the WHO standard limit for drinking water (5 mg/L), its values exceeded LIBNOR guideline for drinking water (1.35 mg/L) in February and December (Table 2).

Nutrients affect the productivity of aquatic systems and an excessive nutrient concentration, particularly of soluble phosphorus and nitrate nitrogen contribute to eutrophisation.

Phosphorous in runoff from fertilized land is usually low because the phosphate ions, having multiple negative charges, are bound strongly to mineral particles in soils. Even with a large input of phosphorous in the Upper Litani River Basin from anthropogenic sources, mainly, agricultural runoff, animal waste, raw sewage and household detergents, Excess phosphates in surface runoff is always a cause for concern since it inevitably leads to what is known as "cultural eutrophication." During eutrophication, phosphates in freshwater lead to a favorable condition for algae and weed growth, which ultimately brings about the rapid demise of an ecosystem through oxygen depletion.

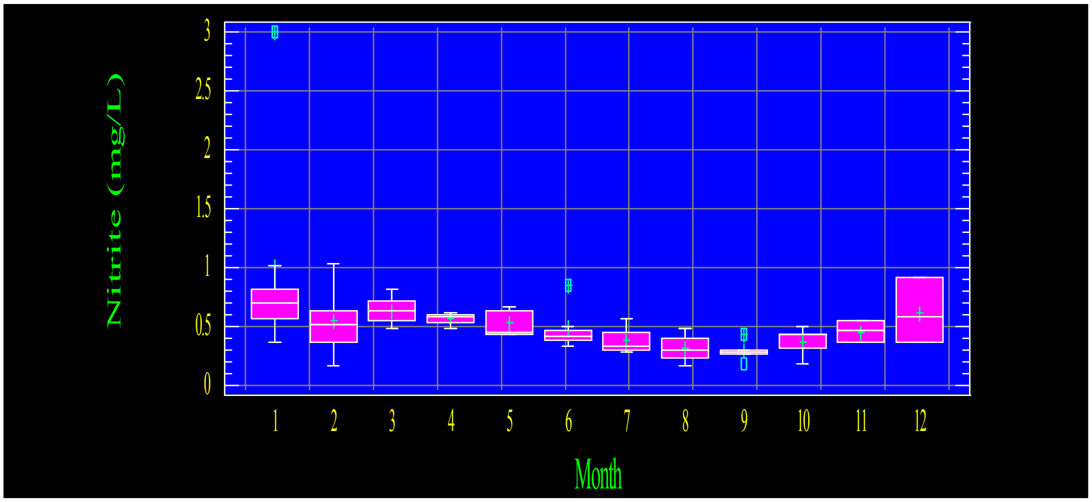

Fig. 14. Concentrations of nitrites from January to December from 2007 to 2012

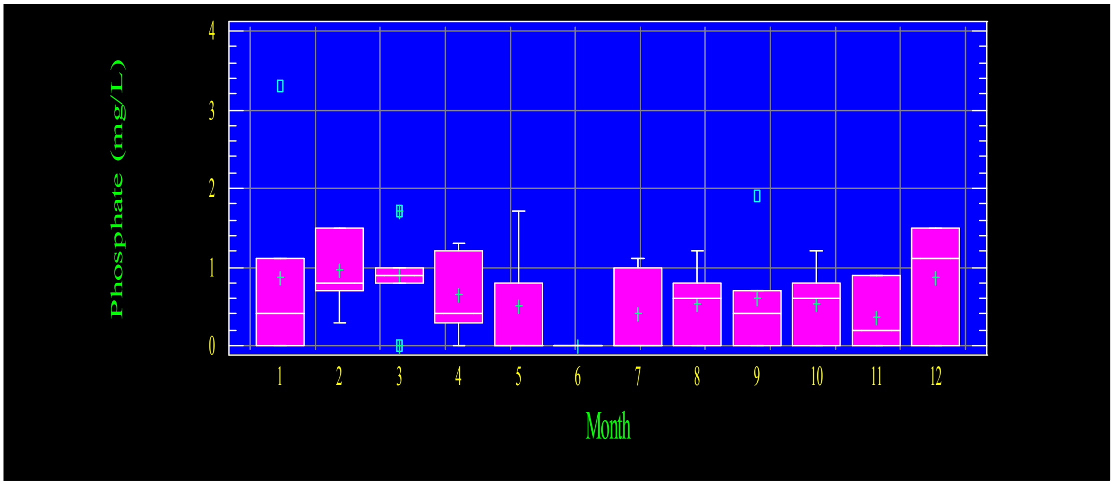

Fig. 15. Concentrations of phosphates from January to December from 2007 to 2012

3.1.1.3.5 Sulfates

(Fig. 16) shows the changes of phosphates concentration from January to December from 2007 to 2012. The concentration of sulfates is between 21 and 41 mg/L.

The concentration of sulfates in January is (29-31 mg/L), this concentration increases to obtain (28-34 mg/L) in March, then it decreases to obtain (29-30 mg/L) in April, this concentration increases to obtain (27-34 mg/L) in June ,then it decreases to obtain (22-28 mg/L) in July, then it increases to obtain (21-30 mg/L) in August, this concentration decreases to obtain (23-27 mg/L), then it increases until it reaches its maximum (22-41 mg/L) in November, finally it decreases to obtain (22-25 mg/L) in December.

The concentration of sulfates over months was between (21-41 mg/L), sulfates in the lake not exceeded (41 mg/L) as shown in Fig. 16. Its values was within the drinking water guidelines given by LIBNOR, EU and WHO (Table 2), this fluctuation in concentration is due to variation of industries' activities.

In light of the following results, sulfates (SO_4^{2-}) in water are usually attributed to atmospheric deposition, industrial runoff, and natural resources such as gypsum and anhydrite.

3.1.1.4 Organic Chemical Parameter

3.1.1.4.1 Dissolved Oxygen

(Fig. 17) shows the changes of the concentration of dissolved oxygen from January to December from 2007 to 2012. The concentration of dissolved oxygen is between 4.7 and 10.6 mg/L.

The concentration of dissolved oxygen in January is (7.3-8.8 mg/L), this concentration decreases in February (6.8-7.5 mg/L), then it increases progressively until it reaches its maximum (10.6 mg/L) in may (8-10.6 mg/L), then it decreases to obtain (6.4-6.6 mg/L) in June, this concentration increases to obtain (6.9-7.3 mg/L) in July, then it decreases to obtain (5.4-6.6 mg/L) in august, then it increases progressively to obtain (4.8-8.5 mg/L) in October, this concentration decreases until it reaches its minimum (4.7-6.9 mg/L) in November, finally it increases to obtain (6.3-7.3 mg/L) in December.

Concentrations of dissolved oxygen (DO) in water are less than 10.6 mg/L, and are low often dropping to 4.7 mg/L in November due to the direct discharge of domestic effluents including raw sewage into rivers before their confluence with the sea [24,25].

DO has no drinking water standard when it comes to LIBNOR, EU and WHO guidelines (Table 2).

The waste discharges added to the preexisting water reduce the concentration of dissolved oxygen as a result cold water species are replaced by warm water species.

The concentration of DO is mainly altered by: Respiration requirements by (plants and animals), also sediments/litter and accumulated organic solids decomposition requirements: which requires oxygen and thus leads to a decrease in DO.

It has diurnal and seasonal fluctuations that are due, in part, to variations in temperature, photosynthetic activity and river discharge, influence of dilution from the river water. Normally, DO is an indicator of the concentration of nutrients and organic matter. Low DO levels are frequently accompanied with high concentrations of decaying organic matter and higher temperatures in the water [26].

Adequate DO is necessary for good water quality. As dissolved oxygen levels in water drop below 5 mg/L, aquatic life is put under stress.

Dissolved oxygen (DO) is vital to aquatic life. It is essential to keep organisms living, to sustain photosynthesis, and for the development of populations. Organic waste from municipal, agricultural and industrial sources may overload the natural system causing a serious depletion of the oxygen supply in the water [27].

3.1.2 Annual Effect

For all parameters there is no annual effect except for nitrates and sulfates from 2007 to 2012. The evolution of pollution for each parameter is limited from 2007 to 2012 to the available data see (Figs.18 and 19). The annual effect of nitrates and sulfates will be studied below from 2007 to 2012:

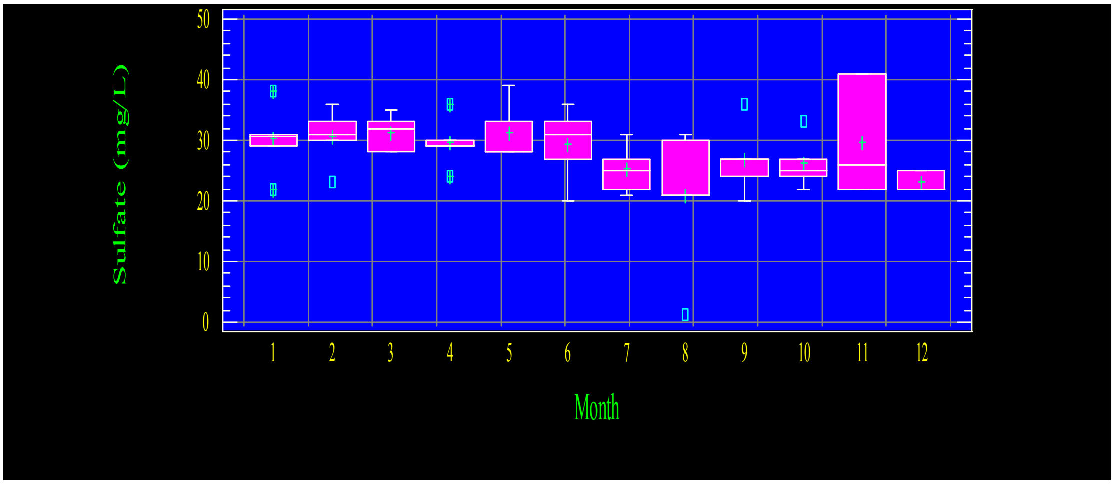

Fig. 16. Concentrations of sulfates from January to December from 2007 to 2012

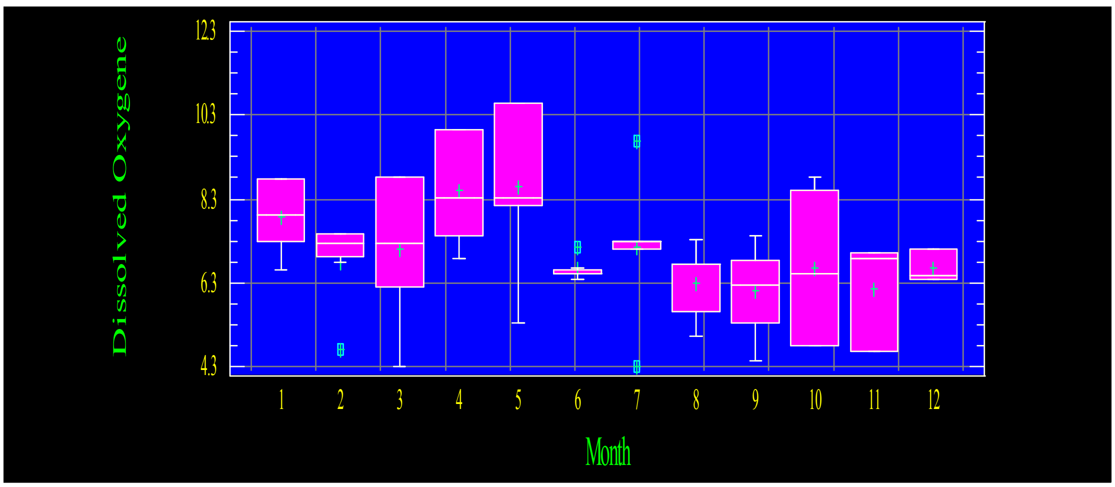

Fig. 17. Concentrations of Dissolved Oxygen from January to December from 2007 to 2012

3.1.2.1 Nitrates

Fig. 18 box and whisker plot shows the variation of nitrates from 2007 to 2012. The concentration of nitrates changes between (6mg/L and 22mg/L).

The concentration of nitrates is (6-12 mg/L) in 2007 and it is the minimal value recorded, this concentration decreases to obtain (7-11 mg/L) in 2008, then it increases to obtain (9-15 mg/L) in 2009, this concentration decreases to obtain (10-14 mg/L), then this concentration increases until it reaches its maximum (16-22 mg/L) in 2011,then it decreases to obtain (16-18 mg/L) in 2012, but for the 2012 we don't have enough data to see the evolution if the concentration of nitrates will increase in the remaining months of the 2012. In where the concentration of nitrates has tendency to increase in 2011 and 2012, but it is within the recommended drinking water guidelines given by LIBNOR, EU and WHO (Table 2).

3.1.2.2 Sulfates

Fig. 19 box and whisker plot shows the variation of sulfate from 2007 to 2012.

The concentration of sulfates changes between (21 mg /L and 36 mg/L).

The concentration of sulfates is (20.5-28 mg/L) in 2007 and it is the minimal value recorded, this concentration increases until it reaches its maximum (31-36 mg/L) in 2008, then it decreases progressively to obtain (27-29 mg/L) in 2010, finally this concentration increases to obtain (31-33 mg/L) in 2012.

The concentration of sulfates increases quickly in 2008, and makes 2008 a special year. The concentration of sulfatesis within the recommended drinking water guidelines given by LIBNOR, EU and WHO (Table 2), this fluctuation in concentration is due to variation of industries' activities.

3.2 AFD and Correlation Approach

Since there were different parameters that may influence the pollution of the Qaraoun artificial Lake water a discriminant factorial analysis (AFD) was conducted. It is a technique used to reduce multidimensional datasets in order to simplify quality evaluation.

AFD studies the discrimination between classes and variables and studies the annual effect of classes.

The approach used to quantifying water pollution and pollution sources derived to the Qaraoun artificial Lake is based on studying parameters and their correlation in conjunction with the resulted data by using a statistical program:

All parameters in this study show that the axis F1 (which represent 40.24% of the variance) was mainly influenced by nitrates, pH, precipitation, nitrites, phosphates and average of temperature, and the axis F2 (which represent 36.64% of the variance) was primarily influenced by sulfates, conductivity, TDS, ammonia, water volume and dissolved oxygen (Fig. 20).

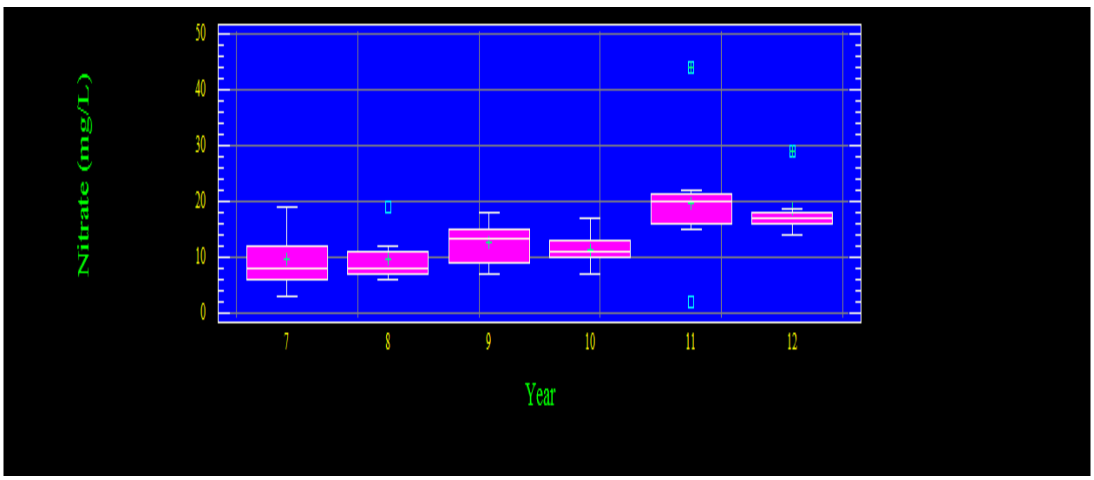

Fig. 18. The yearly variation of nitrates concentration from 2007 to 2012

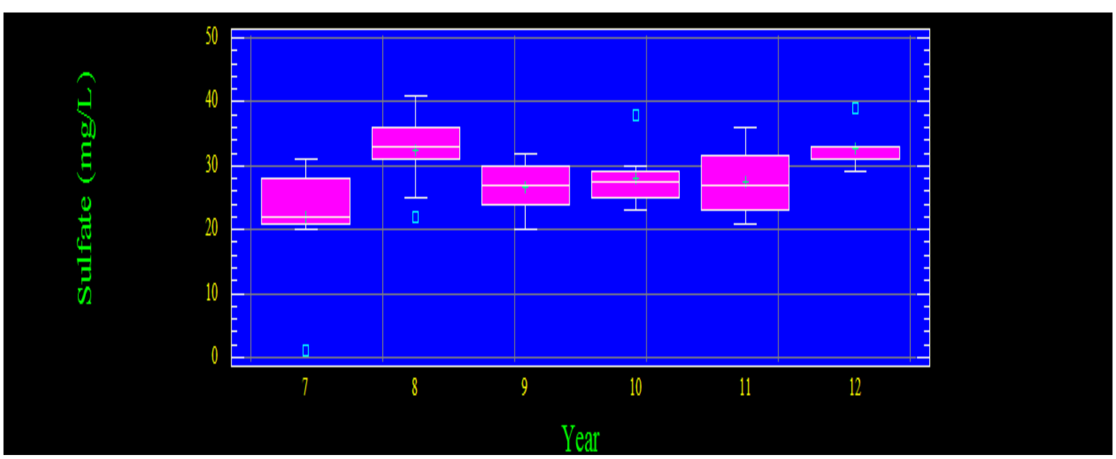

Fig. 19. The yearly variation of sulfates concentration from 2007 to 2012

The table of Pearson correlations shows 7 kinds of correlation:

- High positive correlation ($p < 0.01$) between ammonia and TDS (0.598), between ammonia and conductivity (0.612).
- Positive week correlation ($p < 0.01$) between sulfates and conductivity (0.474), between TDS and nitrates (0.348), between TDS and sulfates (0.470), between TDS and precipitation (0.414), between conductivity and precipitation (0.397), between precipitation and ammonia (0.360) and between nitrate and water volume (0.379).
- High negative correlation ($p < 0.01$) between ammonia and temperature (-0.662), between conductivity and temperature (-0.643), between TDS and temperature (-0.639), and between temperature and precipitation (-0.613).
- Negative week correlation ($p < 0.01$) between pH and TDS (-0.342), between conductivity and pH (-0.353) and between temperature and nitrites (-0.397).
- Positive week correlation ($p < 0.05$) between TDS and nitrites (0.266), between nitrites and conductivity (0.293), between nitrates and conductivity (0.282), and between water volume and temperature (0.274).
- Negative week correlation ($p < 0.05$) is showed between water volume and ammonia (-0.282) and between phosphates and temperature (-0.277).
- Presence of a linear relationship ($p < 0.01$) between conductivity and TDS (0.985), widely visible in the table of Pearson correlations.

The AFD shows that phosphates, precipitation, nitrites and water volume are non-discrimination factors (Fig. 20).

AFD made on yearly parameters shows that the year 2008 is influenced by sulfates and the year 2011 by nitrates; this is due to industrial pollution and fertilizer seepage.

So, because of the week correlation between sulfates and other parameters, sulfates alone makes the 2008 a special year, and for the same reason nitrates makes alone the 2011 a special year by increasing of its concentration in this year (Fig. 21).

The non-discriminant factors didn't show a special variation into years, but only the discriminant factors are shown in (Fig. 21).

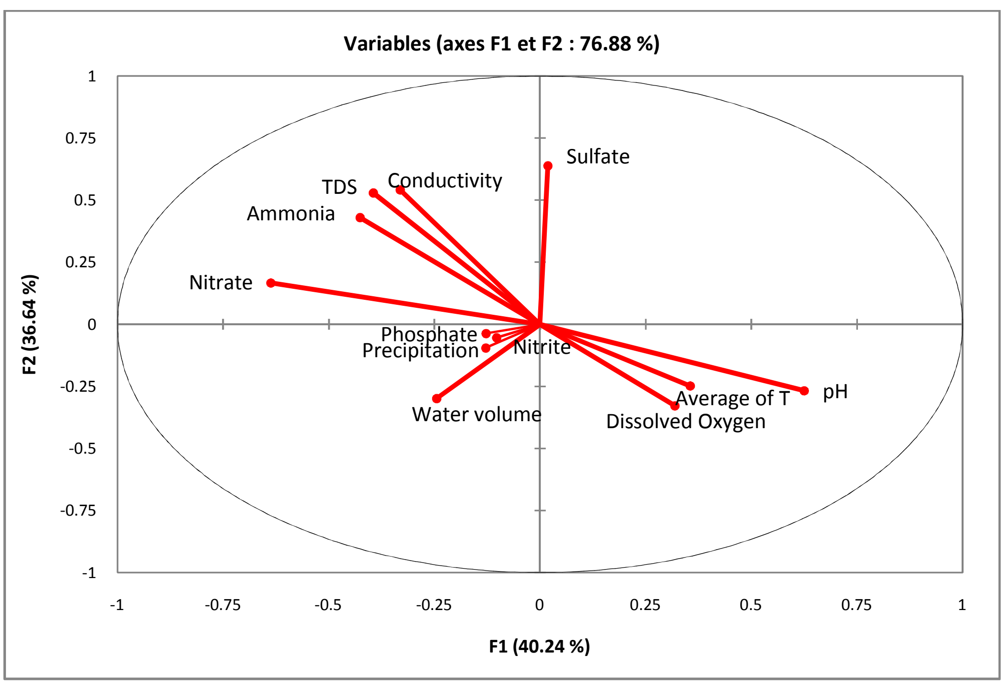

Fig. 20. AFD shows the discrimination and the correlation between parameters

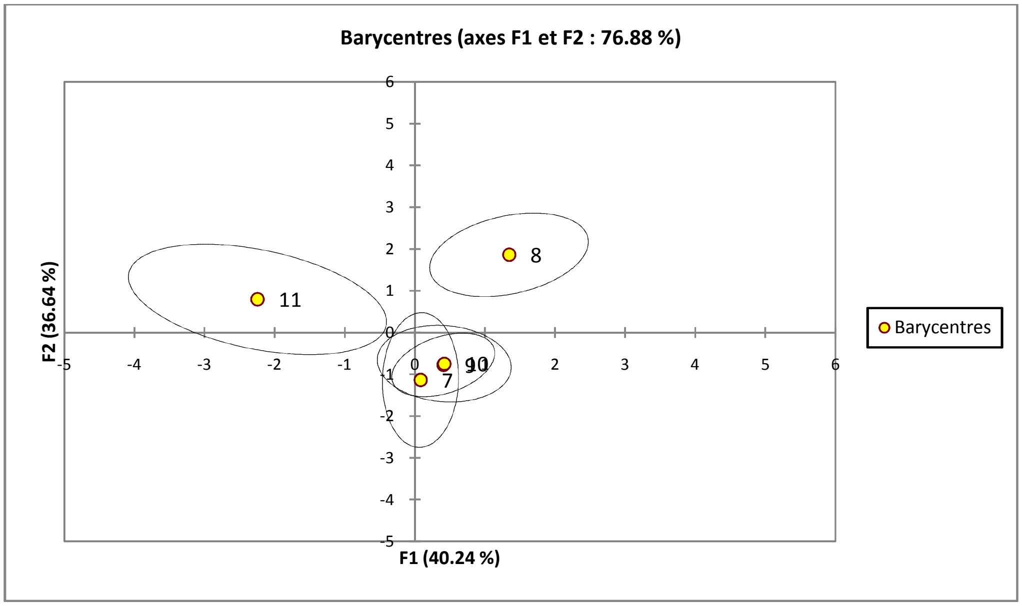

Fig. 21. Discriminant factorial analysis (AFD)

4. CONCLUSION AND RECOMMENDATIONS

The analysis of water quality of the Qaraoun artificial Lake, the largest lake in Lebanon, to identify pollution and it is of great importance to propose their sources on land with a legal protection of lake water.

An effort was made to extract more information from the datasets through the use of statistical programs to study the variance components that shows the following:

There is no annual effect for all water quality parameters except for nitrates and sulfates, furthermore we studied the month effect for all water quality parameters:

- Ammonia values exceeds EU guidelines from November to April between 2007 and 2012, this is due to domestic or industrial wastewater contamination and agricultural activities.
- Concentrations of dissolved oxygen (DO) in water are less than 10.6 mg/L, and are low often dropping to 4.7 mg/L in November between 2007 and 2012. The concentration of DO is mainly altered by: Respiration requirements by (plants and animals), also sediments/litter and accumulated organic solids decomposition requirements: which requires oxygen and thus leads to a decrease in DO.
- Adequate DO is necessary for good water quality. As dissolved oxygen levels in water drop below 5 mg/L, aquatic life is put under stress.
- Low DO levels are frequently accompanied with high concentrations of decaying organic matter and higher temperatures in the water [26], an indication of organic pollution.
- The concentrations found for nitrates are acceptable. They don't exceed drinking water guidelines given by LIBNOR, EU and WHO. This could be related to the excessive release of nitrates enhanced eutrophication and lead to the formation of algal blooms along the lake, thus, the denitrification cause a decrease in the nitrate.
- The concentration of nitrites exceeded over time between 2007 and 2012 the drinking water guidelines given by LIBNOR and EU from November to May, but it was within WHO guideline. The presence of nitrites in water is attributed to denitrifying bacteria occurring in anaerobic conditions.
- The high concentrations of ammonia and nitrites that were found between 2007 and 2012 are indicative of municipal wastewater discharges, and some industrial charges, especially the agro food industries.
- It is noteworthy to mention that pH of the Qaraoun Reservoir over the year between

2007 and 2012 has been between 7.5 and 8.65. Compared to LIBNOR guidelines for drinking water, the pH values exceeded the normal limits in May, July and August, it reaches the maximum in May and July, but pH values were within the recommended range suggested by EU.

So, pH values tend to be basic (>7) and are quasi at acceptable levels. This is indicative of effluent sources of water to the lake and stress on aquatic life. When pollution results in higher productivity (e.g., from increased temperature or excess nutrients), pH levels increase, as allowed by the buffering capacity of the lake.

Although these small changes in pH are not likely to have a direct impact on aquatic life, they greatly influence the availability and solubility of all chemical forms in the lake and may aggravate nutrient problems. For example, a change in pH may increase the solubility of phosphorus, making it more available for plant growth and resulting in a greater long-term demand for dissolved oxygen.

- Phosphates was within the WHO standard limit for drinking water, but its values exceeded LIBNOR guideline for drinking water between 2007 and 2012, and it is due to a fertilizer seepage.
- Sulfates were within the drinking water guidelines given by LIBNOR, EU and WHO between 2007 and 2012.
- The concentration of Total Dissolved Solids(TDS) is in the normal range between 205 and 359 mg/L. This range is acceptable for human consumption as well as irrigation purposes.
- Electrical conductivity (EC) still within the MoE standard between 2007 and 2012.
- The temperature is between 7-27.5ºC between 2007 and 2012, temperature limits weren’t determined since the type of fish living in the lake is not identified and it depends on geography conditions. However field observation showed a large number of dead fish which may be contributed to contamination.
- Water volume increases from January until it reaches maximum in April between 2007 and 2012.

After the study of month effect of all parameters that shows: ammonia, nitrites, dissolved oxygen, phosphates and pH are not within the recommended guidelines suggested by LIBNOR, EU and WHO. Ammonia is the most dangerous because it is toxic to fish and to dialysis patients, its toxicity varies with the pH of the water.

Usually the impacts on the Qaraoun artificial Lake are directly linked to the anthropogenic interference and the hydrologic regime and thus affecting the amount of water and even its quality. Chemical contaminant levels are usually also associated with agricultural activity in the watershed.

The table of Pearson correlations shows 7 kinds of correlation between water quality parameters (negative, positive correlation; week, moderate, strong correlation; linear relationship, with a signification level 1% and 5%).

The AFD revealed some specific features of the data structure that phosphates, precipitation, nitrites and water volume are non-discrimination factors.

The non-discriminant factors didn’t show a special variation into years, but only the discriminant factors do. Either these water quality parameters are found inter-correlated.

Therefore, the AFD made on yearly parameters shows that the year 2008 is influenced by sulfates and the year 2011 by nitrates; this is due to industrial pollution and fertilizer seepage.

In summer period, the Litanibecomes a true open sewer and the Qaraoun artificial Lake is the receptacle [28].

Summary of the suitability of the water for different uses based on the measured parameters:

- Drinking:
  Qaraoun artificial lake has electrical conductivity and total dissolved solids below the accepted limit, but we don’t have fecal coliform data to affirm the suitability of lake as a source of drinking water.
- Irrigation
  Qaraoun artificial lake has electrical conductivity and total dissolved solids below the accepted limit, this makes the lake suitable for irrigation.
  Irrigation using the Lake water can be carried out with restrictions because of the results of other water quality parameters.
- Aquatic life
  pH is above the accepted level.

Temperature limits weren't determined since the type of fish living in the lake is not identified. Dissolved oxygen (DO) is near minimum accepted level.

However field observation showed a large number of dead fish which may be contributed to contamination with other parameters.

Three types of pollution sources were recognized in this study: the plant origin represented by excess use of fertilizers and pesticides, the human origin represented by wastewater, in addition of the waste and contaminated materials, which arise mainly from industrial activities.

In this study, and after determining the existence of pollution in the lake, these results are in conformity with the "Business Plan for Combating Pollution of the Qaraoun Artificial Lake" conducted by ELARD 2011.

Analysis is useful for sustainable development through planning and for implementing remedial measures within time to mitigate the adverse effects of the poor quality of water on human health. Various chemical contaminants can be dangerous to human health at high levels and have devastating impacts on wildlife.

The institutional framework for the water sector in Lebanon is characterized by a myriad of ministries, water establishments, public agencies, municipalities, etc. Key actors in the water sector often duplicate each other's work, other times complement each other, always operating through weak links of communication and responsibility, which have led to a lack of policy focus, with no one institution taking the effective lead of the sector. In addition to fragmented responsibility and weak institutional cooperation, the political conflict in the country retards any progress in developing water plans or strategies.

The failures to apply the environmental laws are due to the political conflicts and instability and this has several aspects. There are several reasons behind the mismanagement of water sector in Lebanon. The gaps in the existing legal framework are that:

- Most of the laws can be described as outdated, unenforceable, overlapping and inconsistent, certain texts have become obsolete and require updating to current scientific and technological advances.
- Existing laws require updating and integration within a well-articulated environmental policy framework.
- Most standards are copied from international standards without any reflection on their applicability and relevance to the local political and socio-economic context.
- The discrepancies between the structure and organization of ministries and public institutions described in legislation and those found on the ground, resulting from understaffing.
- The absence of application decrees for the law 444/2002, even if the existences of EIA (Environment Impact Assessment) decree 8633 in 2012 requires that all sewage treatment plants undergo full Environmental Impact Assessment studies, and the decree 8157 in 2012 about the formation of the National Council for the Environment and define its functions and organization.
- The limited financial resources.
- Some laws awaiting ratification of neighboring countries to implement them.
- The overlap in the mandates of ministries and public institutions, especially with respect to planning, specifying standards and criteria, and wastewater management.
- No sanctions applied.
- No application of the principles of the environmental law 444/2002 (prevention, precaution, polluter/payer, etc.).
- The number of staff fully dedicated to environmental issues at the Central Government level is at present rather low.
- The number of staff at Local Authority / Municipal level only exists in a few Municipal Councils.
- The key to a successful handling of environmental issues are the Local Authorities, viz. the Municipal Councils. That means that these institutions need to be strengthened, both in number and quality.

In addition to the less than expected achievements made, strategy for improvement should be taken into consideration. The following is a list of some of the actions needed to bring Lebanon's water management capabilities into the 21st century:

- Develop a water quality management

strategy for water quality management that includes the private sector.

- Review the existing legal and regulatory framework and develop additional legal texts.
- Review existing standards of enforceability. Pass the pending environmental law and environmental impact assessment laws. Upgrade and update the skills and other capacities of staff.
- Continuous monitoring of the water quality of both the Qaraoun artificial Lake and the streams feeding the lake.
- Establish a self-monitoring and compliance program for industries. Plans should be overseen and enforced by the Ministry of Environment.
- Accelerating the creation of a High Council of Water (previously previewed by the Lebanese Government), which will be the responsible of Integrated water resources management at national level.
- Request to the authorities, especially the municipalities to ensure the prevention of the use of the river bed to drag into it wastes.
- Construction of a sewage treatment plant for wastewater effluents in the villages surrounding the lake.
- Controlling the quantity and quality of fertilizers and pesticides used in agricultural areas surrounding the lake.
- Adopting remote sensing techniques for future studies on water sources.
- Implementation of the national decennial strategic plan for the water sector (2000-2010) created by the ministry of energy and water.
- Application of principles environmental laws such as prevention, precaution, polluter/payer, etc.
- Promulgation of decrees for managing the Qaraoun artificial Lake and reduce the pollution.
- Ensure that the water sector reform process in Lebanon is undertaken in a coherent and integrated way, based on realistic objectives within the socio-economic and political contexts.
- Management of the water resources involving legal and institutional tools should be suitable for all water sectors (drinking, irrigation, sanitary, flood mitigation and reuse). The application should be made with the involvement of scientific, technical, economic and financial instruments which are properly adapted for the social and cultural Lebanese environment.
- After participating in international conferences, Lebanon should ratifies international conventions and apply them.
- Climate change problems require us to act locally but think globally, we should start thinking of solutions and act now not later. The application of climate change laws should concern all sectors in Lebanon, not only the water sector.

Furthermore, several other actions could be implemented:

- Introduce in the education program of the universities the principles of Best Practices for the Integrated Water Resources Management and the potentials of their application in Lebanon.
- Conduct information and awareness campaigns in the universities and to the public at large, for encouraging water saving practices.

Finally, we recommended for next studies to take more samples from different sites in the Qaraoun artificial Lake and make the repeatability and reproducibility of methods and samples.

Where the environmental problems frequently need legal issues and its resolution demands knowledge of law and the environment, we believe in the importance of application of the environmental impact assessment (EIA) for all establishments existing near the Litani River and the Qaraoun artificial Lake to reduce water pollution respecting the principles of the environmental law 444/2002 (prevention, precaution, polluter/payer, etc.) and the application of sanctions relative to each kind of emission.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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