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Eutrophication Process in the Mujib Dam

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Abstract

This study aims at analyzing the physical, chemical, and biological components of the water stored in Mujib dam as related to eutrophication processes. Several seasonal water samplings starting from the year 2006 until summer 2010 were carried out, analyzed and interpreted. The results showed small variations in the pH and EC values of the Mujib dam water. The EC in winter time were low compared to summer time as a result of dilution process by floodwater. In addition, the concentration of major cations and anions were found to be higher in summer season due to evaporation. Moreover, it was found that the concentrations of NH_4^+ and heavy metals are lower than the permitted level in drinking water according to the Jordan standards for drinking purposes. The concentrations of chlorophyll "a" and the Plankton counts were very low. This study shows that factors like high nutrient concentration, high sun illuminations, suitable pH, high temperature, and the low velocity of water should lead to the eutrophication processes in the Mujib dam water, but, the eutrophication processes is very limited and do not reach to the level of algae blooms.

Keywords: Eutrophication; Mujib Dam; Algal blooms; Nutrients; Organisms.

1. Introduction

The main problem seems to face the use of surface water for domestic purposes in semi-arid regions is eutrophication of surface waters bodies which results from direct or indirect result of anthropogenic activities (Salameh, 1985).

Nutrients, such as nitrogen, phosphorus and silicate Silica in lakes, reservoirs and some streams, rivers, and near shore marine water are prerequisites for life, and do not form an environmental problem. Nutrients are not pollutants but life givers (Carpenter *et al*., 1998; Hornung *et al*., 1995). They become a problem when too large inputs affect the original character, properties or functions of the ecosystem. When this occurs, it is referred to as eutrophication. Eutrophication is characterized by the presence of sufficient planktonic, algae and water weeds, which cause water quality impairments for use in domestic water supply.

The human factors affecting water quality are generally associated with the type and level of development activities within the catchments of a water body. The presence of human activity in a public water supply area is considered as a potential risk to water quality impairment. In addition, human activities can accelerate the rate at which nutrients enter ecosystem. Runoff from agriculture and development, pollution from septic systems and sewers and other human related activities increase the flux of both inorganic nutrients and organic substances into terrestrial, aquatic, and coastal marine ecosystems (Anderson, 1994; Bartram *et al*., 1999; Ongley, 1996). Beside nutrient inputs, some physical conditions support eutrophication development. Thermal stratification of water bodies, (such as lakes and reservoirs), temperature and light influence the development of aquatic algae (WHO, 2002; Schramm, 1999).

The aim of this work is studying the chemical parameters in Mujib dam water, which could lead to the Eutrophication processes such as PO_4^{-3}, NO_3^-, and SiO_2. In addition to the other physical, chemical and biological water constituents of Mujib dam such as (EC, pH, Na^+, K^+, Ca^{2+}, Mg^{2+}, NH_4^+, HCO_3^- CO_3^{2-}, Cl^-, SO_4^{-2}, BOD5, COD, TOC, Chlorophyll "a", Plankton count, Total Coli forms and Escherichia coli.).

Previous investigations had already studied the eutrophication process in Jordan especially in the upper Jordan River regions (Salameh, 1985; Al-Khory, 2005; Khalil and Jamal 2007; Hailat and Manasreh, 2008; Manasreh *et al*., 2009; Al-Harahsheh, 2010; Al-Harahsheh and Salameh, 2010; and Sophia, 2010).

The Hashemite Kingdom of Jordan is located within the Eastern Mediterranean Basin between latitudes [-110000-255000] N and longitudes [121000-570000] E, according Palestine Grid 1924 (PG) coordinates system (Figure 1), covering a land area of approximately 88.500 km^2 (NWMP, 2004).

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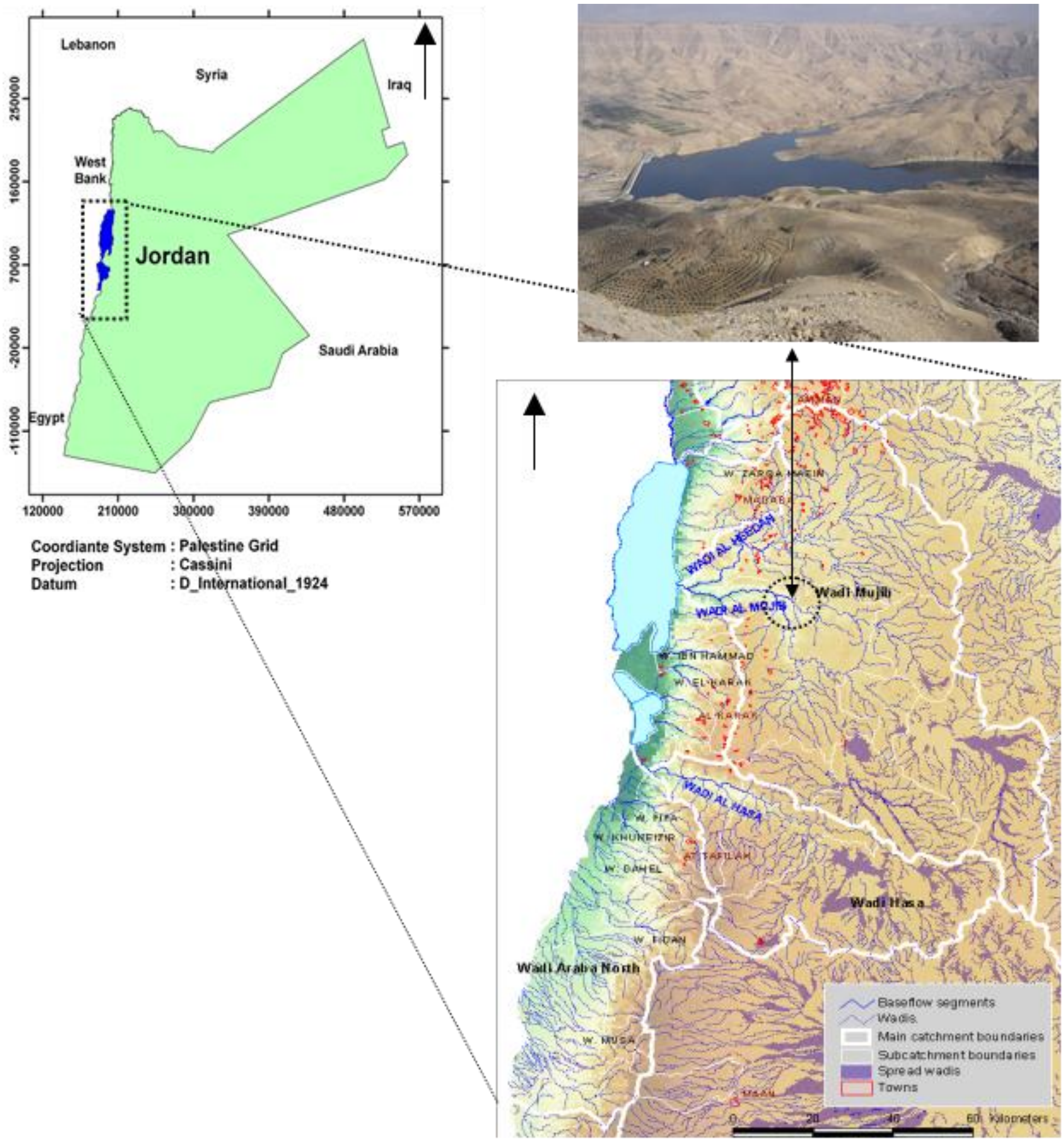

Figure 1. Location map of Mujib Dam (Photo) and its catchments area in Jordan.

Jordan has a limited amount of rain fall and, hence, limited surface and ground water resources. Jordan dose not posses Rivers in the World-Wide known scale, except the Jordan Rivers which used to discharge around 1400MCM/y into the Dead Sea before the development of the water resources in its catchments area (Al-Ansari and Salameh, 2006). Other surface water resources in Jordan are found in the Yarmouk and Zarqa Rivers and in wadis like Karak, Mujib, Hasa, Yabis and El-Arab, in addition to flood flow wadis in the different parts of the country (Al-Ansari and Salameh, 1999). Jordan built many dams to store flood water along the main rivers and wadis such as King Talal Dam, Wadi El-Arab Dam, Wadi Ziglab Dam, Kafrein Dam, Wadi Shueib Dam, Al Karameh Dam, Wala Dam, Tannour Dam, Mujib Dam and many desert dams. Figure 3 show the location of some of these dams.

The Mujib Wadi is located between latitudes [95393 - 137739]N, and longitudes [205442 - 244775]E .The Wadi Mujib system comprises the Wala, Swaqa, Heidan and Mujib, with total catchments area of about 6.700 km^2 (Al-Assa'd and Abdullah 2010; NWMP, 2004). On the other hand, Wadi Hasa catchments area is about 2,600 km^2, (NWMP, 2004) (Figure 1).

Perennial flow for both Wadi Mujib and Wadi Hasa is restricted to the downstream reaches, where ground surface elevation is below 400m BSL (below sea level). The base flow originates primarily from the continuous array of springs within the Dead Sea escarpment, and partly from the Ajloun Group and the lower sandy aquifer systems (Kurnub sandstone) (NWMP, 2004).

The average annual precipitation is 154 mm and ranges from 300 mm in the northwestern part of the watershed to 50 mm or less in the southeastern corner, and the average annual potential Evaporation is 2200 mm (DOM, Open files).

Wadi Mujib downstream of the confluence of wadi Heidan discharges an average amount of 83 MCM/y directly into the Dead Sea. Half of the river flow consists of base flow and the other half of flood flows (DOM, Open files).

The catchments area is sparsely inhabited, with moderate agricultural activity and almost no industry; therefore, industrial pollution is not a major issue in the Wadi Mujib area (Al-Ansari and Salameh 2006).

The Mujib dam aiming at exploiting floods flows to provide water to the Arab Potash company, the Dead Sea chemical complex, the tourist's area at the eastern shore of the Dead Sea and drinking water to Amman city (Mahasneh, 2001). Land uses/ land covers of Mujib catchments area are strongly influence the chemistry of lake water and its temporal variations. Of the major land uses of Al-Mujib catchments area and its lake the followings: Cultivated land and livestock farm, Gypsum mines, Disposal of wastewater in cesspits, fishing in the lake (Margane *et al*., 2008).

2. Methodology

Water samples were collected during the period 2006 to 2010 and analyzed in the laboratories of Water Authority of Jordan; In addition parallel samples were collected and analyzed in the laboratories of Institute of Earth and Environmental Science at Al-al Bayt University.

Samples were collected monthly from the lake surface in polyethylene bottles (1000 ml) for chemical analysis and in sterilized glass bottles for microbiological analysis and transported to the laboratory. In addition, pH and EC measurements were conducted in the field using portable meter.

The analysis of Na^+, K^+, Ca^{2+}, Mg^{2+}, NH_4^+, HCO_3^-, CO_3^{2-}, Cl^-, SO_4^{2-} , PO_4^{3-} , NO_3^- , SiO_2, B, Cd, Cr, Fe, Pb, Mn, Ni, Zn, dissolved non-specific organic compounds measured as BOD_5, COD, and TOC, chlorophyll "a", plankton count, total Coli forms and Escherichia Coli were analyzed according to the Standard Methods for Examination of Water and Wastewater. The total bacterial count was determined by incubating on a nutrient in agar plate at 28°C for 48 hour. Total Coliforms count and fecal Coliforms were determined using multiple tube fermentation. The total Coliforms numbers were estimated in a lauryl Tryptose broth and the tubes were incubated at 37°C for 24 to 48 hours. For fecal Coliforms count, *Escherichia Coli* were incubated at 44.5°C for 24 hours.

The analytical methods which have been used to analyze the water samples are listed in (Table 1).

Table 1. Analytical methods used for measuring hydrochemical and biological parameters of the water samples.

Parameter	Unit	Analytical Method
EC	µS/cm	Field EC probe
pH	Value	Field pH electrode
Na^+	mg/l	Flame Photometer
K^+	mg/l	Flame Photometer
Ca^{2+}	mg/l	Titration method
Mg^{2+}(TH-Ca^{2+})	mg/l	Titration method
Cl^-	mg/l	Ion Chromatographic system
HCO_3^-	mg/l	Ion Chromatographic system
CO_3^{2-}	mg/l	Ion Chromatographic system
NO_3^-	mg/l	Ion Chromatographic system
SO_4^{2-}	mg/l	Ion Chromatographic system
PO_4^{3-}	mg/l	Ion Chromatographic system
SiO_2	mg/l	Spectrophotometer
NH_4^+	mg/L	Ammonia Selective Electrode
BOD_5	mg/L	5 day BOD Test (Ref. WW-BOD_5-R003)
COD	mg/L	Closed Relux Titration Method (Ref. WW-COD-R005)
TOC	mg/L	Per sulfate-Ultraviolet Oxidation
Heavy metals (B, Cd, Cr, Fe, Pb, Mn, Ni, Zn)	µg/l	ICP-OES (Coupled Plasma Optical Emission Spectroscopy)
Plankton Count	Unit/ml	Concentration by Sedimentation Technique
Chlorophyll "a"	ppb	Fluorometric Determination (Ref:MIC-CHA-R*003)
Total Coli forms	MPN/100 ml	Multiple Tube Fermentation (Ref:MIC-TFC-R*003)
Escherichia coli	MPN/100 ml	Multiple Tube Fermentation (Ref:MIC-TFC-R*003)

3. Result and Discussion

The concentration of the different parameters is affected by the different water source, large variations input water flow, water velocity, human activity and the climatic variations between winter and summer seasons. The seasonal average of some chemical laboratory analyses of water samples are listed in (Table 2).

Table 2. Seasonal average of chemical and biologic laboratory analyses of water samples.

Sampling Time	pH	EC (μS/cm)	Na^{+} (mg/l)	K^{+} (mg/l)	Ca^{+2} (mg/l)	Mg^{+2} (mg/l)	HCO_3^{-} (mg/l)	Cl^{-} (mg/l)	SO_4^{-2} (mg/l)	Chlorophyll (ppb)	Escherichia coli	Total coliform
W 2006	7.9	1754	201.7	15.6	119.2	50.9	182.3	375.2	305.5	0.86	2700	13000
Sp 2006	8.1	1790	180.7	11.7	135.8	56.0	130.0	335.4	480.4	1.08	7500	6800
Su 2006	8.2	1761	183.4	14.6	103.5	40.5	157.1	332.6	196.9	1.05	5169	4483
W 2007	8.2	1326	51.6	6.9	67.8	21.6	161.3	68.1	153.4	1.04	2305	4328
Sp 2007	8.2	1269	44.3	5.7	61.7	21.0	155.7	65.8	139.2	1.15	2760	13667
Su 2007	8.1	1483	65.1	5.8	70.7	25.3	168.5	90.8	161.9	1.2	2760	3160
W 2008	8.1	969	76.5	5.8	80.4	28.1	186.5	99.8	180.3	1.17	1453	3658
W 2009	8.2	1254	52.4	6.2	68.8	20.2	160.9	67	154.1	0.95	318	690
Sp 2009	8.2	1566	212.5	14.4	147	48.2	226.9	424.2	174.4	1.03	1083	1113
Su 2009	8.1	1289	113.2	12.9	83.8	31.2	143.8	191.8	170.2	1.12	800	255
W 2010	8.3	1360	236.2	15.9	118.2	47.8	154.9	434.7	238.2	1.04	1273	2530
Sp 2010	8.3	1683	240.3	14.3	112.2	44.7	134.2	425.6	240.3	1.08	1680	1500
Su2010	8.3	1820	252.1	16.0	125.6	50.9	163.5	453.4	244.3	1.16	2400	1360

3.1. Physical Parameters (pH, EC)

3.1.1. ***pH*** *Value*

The pH value for the Mujib Dam water shows small variations between summer and winter samples (Figure 2). The average pH value ranged between 7.93 in winter 2006 to 8.32 in summer 2010 and these values are considered suitable for drinking water (Figure 2).

Furthermore, a general trend of pH increasing during the period 2006 and 2010 is clearly shown (Figure 2), this could be attributed to the dissolution of basic minerals such as carbonates (limestone, dolomite, calcite,..) and clay minerals that found along the course of tributaries of Mujib catchments area, which eventually increases the water lake alkalinity and hence its acidity.

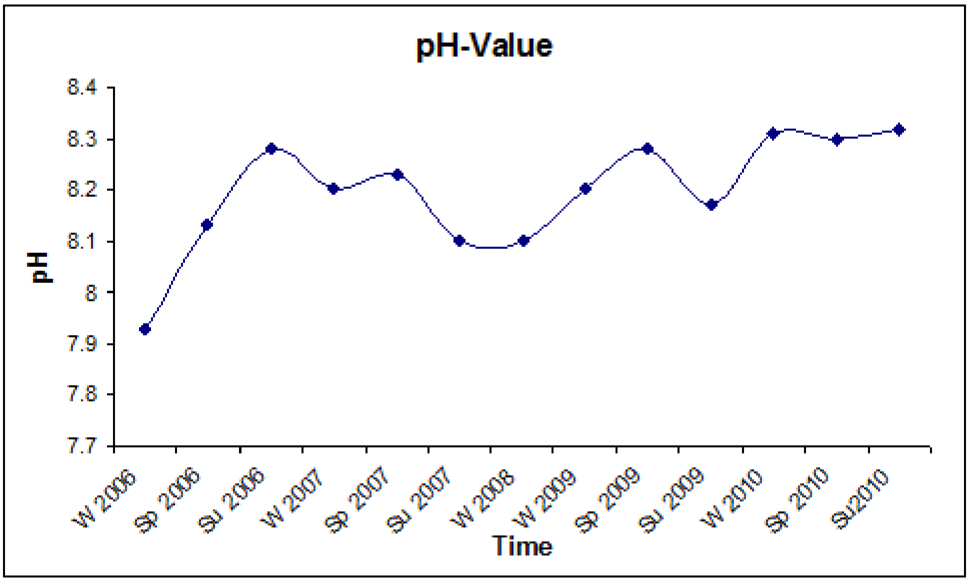

Figure 2. Temporal Variations of the average pH of the Mujib Dam water during the period (2006-2010), (W: Winter, Sp: Spring, Su: Summer)

3.1.2. Electric Conductivity (EC)

In general, the EC value is a good indicator for water salinity and hence its quality, the EC value in summer seasons was found to be higher than it in winter seasons due to dilution by floodwater during winter (Figure 3). The average EC value ranged between 969µS/cm in winter 2008 and 1820 µS/cm in summer 2010. Furthermore, Figure (3) shows a gradual decrease in the EC values from around 1800µS/cm in W2006 until it reaches 969 µS/cm in W2008, then a gradual increase in the EC until it reaches around 1800µS/cm in 2010, these variations could be attributed to different interrelated factors such as: dissolution processes, rainfall, lake water level, evaporation (e.g. the higher evaporation rate, the higher concentration of ions and higher EC and salinity values).

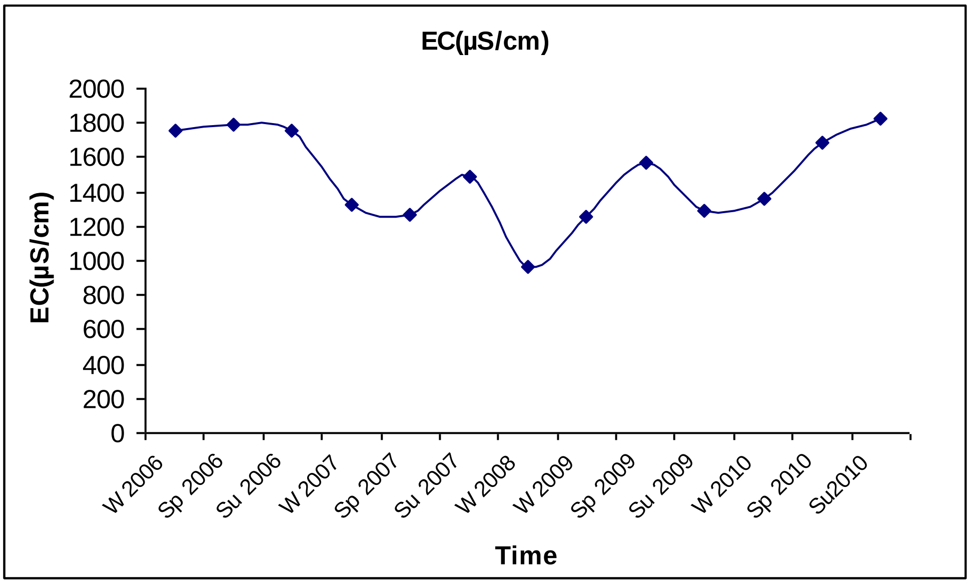

Figure 3. Temporal Variations of the average EC of the Mujib Dam water during the period (2006-2010)

3.2. Chemical Parameters

3.2.1. Cation concentration

The cations Na^+, K^+, Ca^{2+}, Mg^{2+} and NH_4^+ concentration ranged between 44.3, 5.87, 61.72 and 20.21 mg/l to 252.13, 16.03, 147.09 and 56.06 mg/l respectively.

The variations between cations concentration in 2006 and 2010 were found to be higher than 2007, 2008, and 2009 due to differences in the average. The average values of cation concentration during summer seasons are higher than winter seasons due to the high evaporation in the summer time except 2006 (Figure 4).

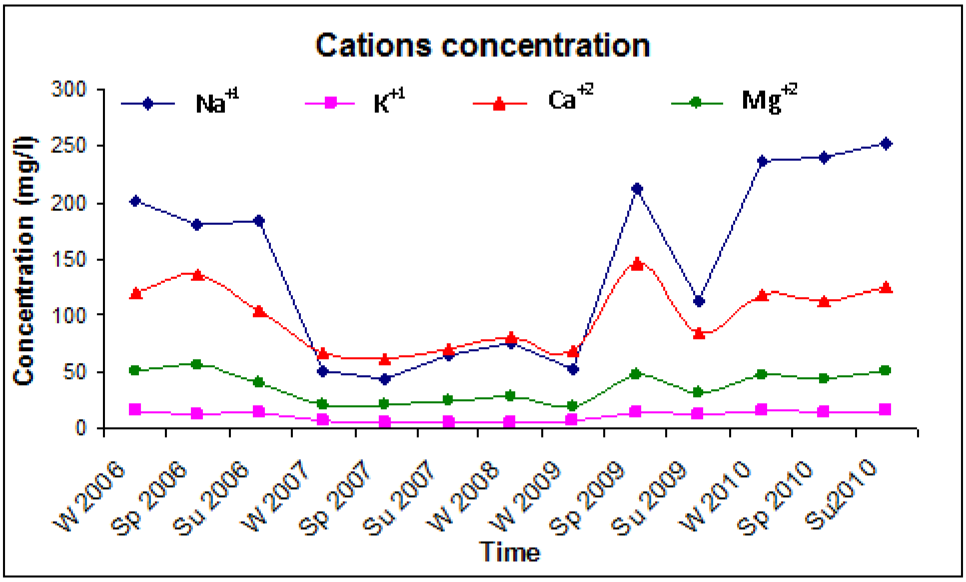

Figure 4. Temporal Variations of the average cations concentration of the Mujib Dam water

The result of the ammonium (NH4+) analyses in all samples was found to be less than 0.1mg/l may be because no waste water recharge in these area which reflecting the sparsely inhabited catchments area.

3.2.2. Anions concentration

The anions HCO3-, CO32-, Cl- and SO42- concentration ranged between 130.07, 0, 67 and 139.2 mg/l to 226.92, 12, 454.76 and 480.48 mg/l respectively. Most the average value of the anions concentration during summer seasons were higher than during winter seasons and this difference due to the evaporation in the summer seasons with the exception of 2006. The Cl- concentration in 2007 and 2008 was less than in 2006, 2009 and 2010 while the concentration of CO3-2 equal zero except during the spring of 2009 and spring 2010. The cations Na+, Ca2+ and anions Cl- , SO4-2 concentration are higher than another cations and anions in Mujib Dam due to dominated the halite and gypsum salt in the Mujib Dam catchments area (Figure 5). In addition to Gypsum mining activities, unsewered houses inside the catchments area could be considered another source of higher sulfate concentration (Figure 5).

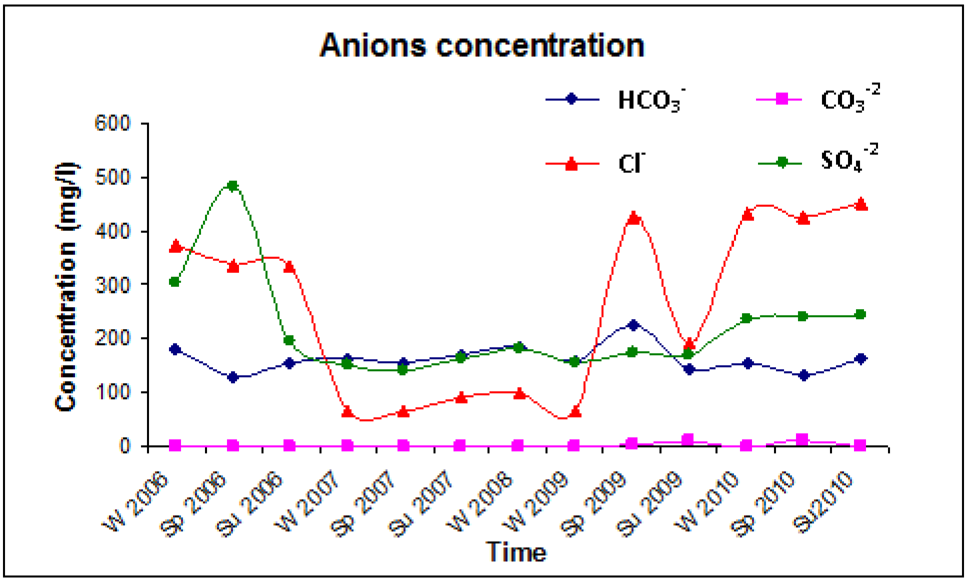

Figure 5. Temporal variations of the average anions concentrations of the Mujib Dam water

3.2.3. The Nutrients (PO43- , NO3- , SiO2)

The PO_4^{3-} , NO_3^- and SiO_2 concentrations ranged between 0.01, 0.94 and 0.356 mg/l to 0.177, 3.98 and 15.55mg/l respectively. In general**,** the average value of (PO_4^{3-} , NO_3^- , SiO_2) concentrations in winter is higher than in the summer seasons except 2006 due the flushing of the soil by the run off (Figure 6). The concentrations of the nutrients are above the Eutrophication level, combined with high temperatures, high light intensity, when eutrophication processes seems to be inevitable. The NO_3^- and PO_4^{-3} concentrations are necessary for the eutrophication process 0.2-0.3 and 0.01 mg/l respectively (Lee and Lee, 2005), (Figure 6). The main sources for nutrients are disposal wastewater in cesspits, chicken farms and cultivated lands inside Mujib dam catchments area. The higher values of silica contents could be attributed to the dissolution of sandstone of Kurnub Formation or clay deposits in the study area.

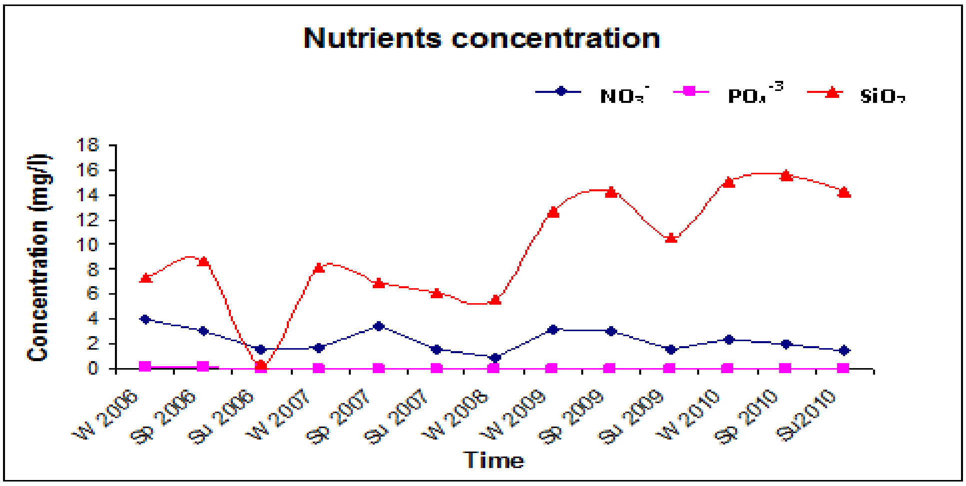

Figure 6. Temporal Variations of the average nutrients concentration of the Mujib Dam water

3.2.4. Trace Elements

Trace elements and heavy metals in Wadi Al Mujib dam water (Table 3) may be resulted from human activity such as mining and processing industrial, operation of fuel-driven boat and weathering of rocks such as Oil shale in surrounding regions where the flow direction from Lajjoun area could reach Al-Mujib dam in a few hours (Al-Harahsheh *et al*., 2010).

Table 3. Average concentration of Trace Elements in Mujib Dam water**.**

Time	B (μg/l)	Cd (μg/l)	Cr (μg/l)	Fe (μg/l)	Pb (μg/l)	Mn (μg/l)	Ni (μg/l)	Zn (μg/l)
W 2006	0.22	<0.003	<0.01	0.22	<0.01	0.23	<0.01	<0.04
Sp 2006	0.25	<0.003	<0.01	<0.1	<0.01	<0.01	<0.01	<0.06
Su 2006	<0.003	<0.003	<0.01	<0.1	<0.01	<0.01	<0.01	<0.06
W 2007	0.45	<0.02	<0.02	<0.2	<0.01	0.06	<0.02	<0.06
Sp 2007	0.28	0. 02	0.02	<0.4	<0.01	0.15	<0.02	<0.06
Su 2007	0.3	<0.003	<0.02	<0.1	<0.01	<0.02	<0.02	<0.06
W 2008	0.22	<0.003	<0.01	<0.1	<0.01	<0.01	<0.01	<0.06
W 2009	0.4	<0.02	<0.02	<0.1	<0.01	<0.06	<0.02	<0.06
Sp 2009	0.34	<0.02	<0.02	0.24	<0.01	<0.06	<0.02	<0.06
Su 2009	0.33	<0.01	<0.02	<0.2	<0.01	<0.08	<0.02	<0.06
W 2010	0.2	<0.003	<0.02	<0.1	<0.01	<0.02	<0.02	<0.06
Sp 2010	0.3	<0.003	<0.01	<0.1	<0.01	<0.01	<0.01	<0.06

Table 3 shows that the concentration of trace elements and heavy metals were below the below the maximum permissible limits according to the Jordan Standards specification.

3.3. Dissolved Non-specific organic compounds.

The dissolved non-specific organic compound (Biological oxygen demand (BOD_5), Chemical oxygen demand (COD), Total organic carbon (TOC)), were analyzed in the Mujib dam water.

3.3.1. Biological oxygen demand (BOD5)

The result of BOD_5 concentration in all samples for the 2006, 2007, 2008, 2009 and 2010 are less than 10 mg/l.

3.3.2. Chemical oxygen demand (COD)

The result COD concentration in all seasons are less than 20 mg/l except winter 2007 and winter 2008 are less than 30 mg/l but more than 20 mg/l.

3.3.3. Total Organic Carbon (TOC)

The result of **TOC** concentration analyses in all samples are less than 2 mg/l.

3.4. Biological parameters:

Chlorophyll "a", Plankton count, Total Coli forms and Escherichia cilia were analyzed to present the biological parameters in the Mujib dam water.

3.4.1. Chlorophyll "a" and Plankton count

The chlorophyll "a" concentrations show small variations between summer seasons and winter seasons, where the average value ranged between 0.86 ppb in winter 2006 to 1.24 ppb in summer 2007.

The concentration of chlorophyll "a" was found to be higher in the summer than in the winter due to high temperature, nutrients availability and high intensity of light. However, in general the concentration of chlorophyll "a" is very low in Mujib dam water compared with other dams in Jordan (e.g Wadi Al Arab, King Talal Dams and King Abduallah Canal (KAC)) (Al-Harahsheh, 2007) (Figure 7).

Table 4 shows the result of plankton count analyses in all samples from winter 2006 to summer 2010, the Plankton count in the summer time higher than winter time where it is not seen in winter time except winter 2008 and 2009. The Plankton count in the summer time ranged between 4 in summer 2006 to 14 in summer 2010. The numbers of the Plankton count were found to be very low indicating that the concentration of the algae are very small and the occurrence of Eutrophication blooms is limited in Mujib dam.

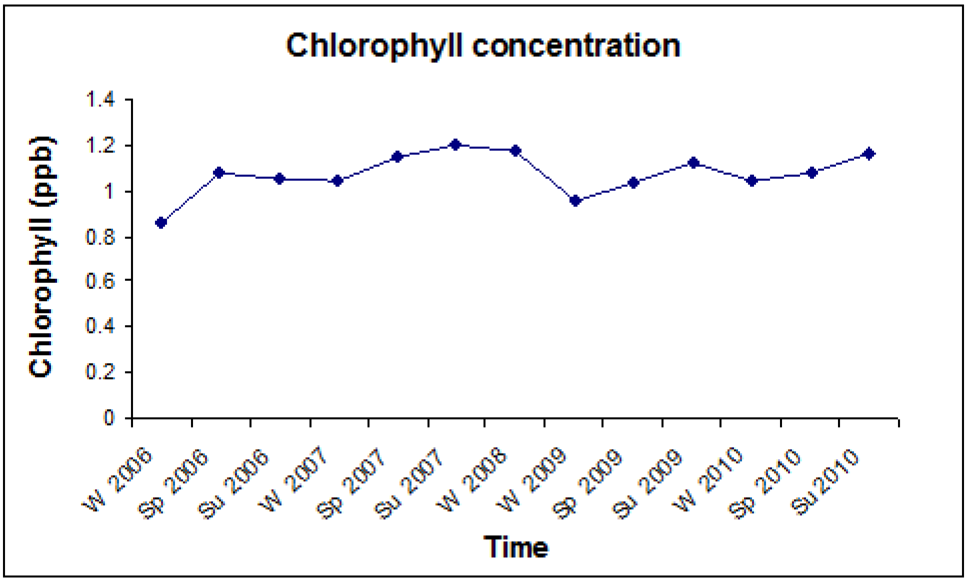

Figure 7. Temporal variations of the average Chlorophyll "a" concentration of the Mujib Dam water

Table 4. Average Plankton count in Mujib Dam water.

Time	Plankton count(unit/ml
W2006	Not Seen
S2006	4
W2007	Not Seen
S2007	6
W2008	10
W2009	Not Seen
S2009	11
W2010	5
S2010	14

The bacterial count plays an important role in the biological process because heterotrophic bacteria break down organic matter into smaller molecules and carbon dioxide. The presence of Coliforms, particularly fecal Coliforms is an indication of the presence of associated pathogens. Thus, determination of Coli forms and fecal Coli forms in water is essential as water quality parameters (Al- Harahsheh, 2007). The analyses of Escherichia Coli and total Coli forms are presented in (Figure 8) for whole samples. The average Escherichia Coli number ranged between 318 in winter 2009 to 7500 MPN/100ml in spring 2006, while the total Coliforms ranged between 255 in spring 2009 to 13667 MPN/100ml in spring 2007, the average Escherichia Coli number was higher in summer seasons than winter seasons and the average total Coli forms in winter seasons higher than summer seasons. The main sources of fecal Coli form and Escherichia Coli in lake water are unsewered houses and the livestock farms.

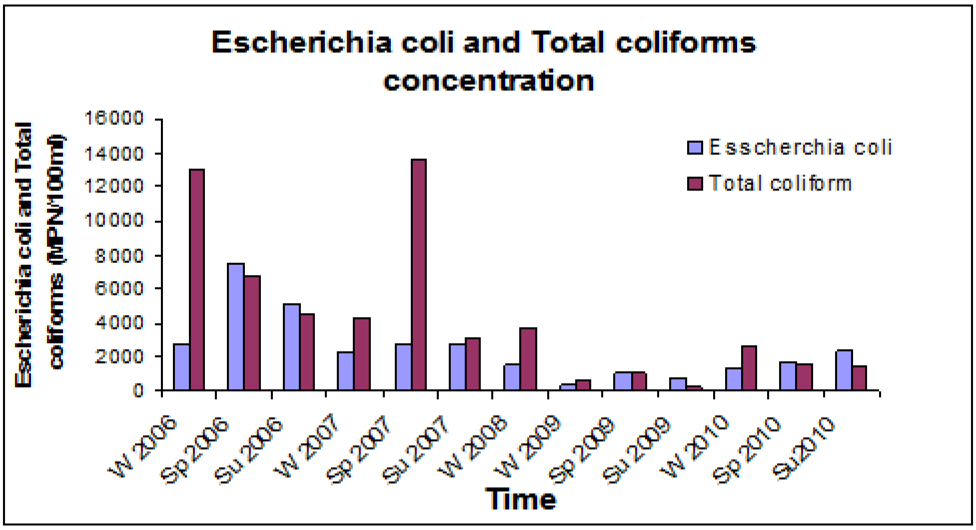

Figure 8. Temporal variations of the average Escherichia Coli and total Coli forms numbers value of the Mujib Dam water

4. Conclusions

- EC and pH showed small variation as a result of the feeding waters originating from the same geographic area.
- The major cations (Na^+, K^+, Ca^{2+} Mg^{2+}), major anions (HCO_3^-, CO_3^{-2}, Cl HCO_3^-, CO_3^{-2}, Cl^- and SO_4^{-2}), NH_4^+ and trace elements and heavy metals concentrations are less than permissible limits assigned by the Jordan Standard for drinking water, thus the Mujib dam water can be used as a drinking waters sources.
- Biological oxygen demands (BOD5), Chemical oxygen demand (COD), Total organic carbon (TOC), are lower than Jordan Standard for drinking water.
- The chlorophyll "a" concentration and Plankton count are very low and the mean the eutrophication is very limited in Mujib dam.
- All these factors (high nutrient concentration, high sun illuminations, suitable pH, high temperature, and the low velocity of water) are available to cause eutrophication processes. All these conditions provide ideal environment for big variations of algal species to grow and increase in numbers forming algal blooms. Nevertheless, the occurrence of Eutrophication blooms is limited in Mujib dam. The UV radiation which may restrict eutrophication process.
- The Mujib Dam water quality was affected by the climate and topography of the region (e.g. soil type and intensity of rainfall intensity…etc.) rather than with the effects of anthropogenic influence.

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