Current World Environment Vol. **10**(1), 39-54 (2015)

Physical and Biochemical Characteristics of Sharhabiel Reservoir water, NW Jordan

NAZEM M.EL-RADAIDEH

Department of Earth and Environmental Sciences, Faculty of Science,
Yarmouk University, Irbid-21163, Jordan.

http://dx.doi.org/10.12944/CWE.10.1.05

(Received: January 16, 2015; Accepted: Feburary 17, 2015)

ABSTRACT

Jordan relies heavily on rainwater stored in reservoirs because it has extremely limited alternative water resources. These reservoirs are essential for drinking water and irrigation, so monitoring their water quality is extremely important. Variations in physical and biochemical conditions were investigated at Sharhabiel Reservoir (Jordan). Water quality monitoring of Sharhabiel Dam, from January to December 2013 indicates that the dam is subject to agricultural runoff. It also revealed that mineral dissolution, sediment load, rainfall evaporation and pumping, are the major contributors to variations in water quality. The water chemistry of the impounded Sharnabiel Reservoir showed that Na, Ca, Mg, HCO_3, and Cl are the principal ions, reflecting the dominance of calcareous weathering, with some contribution of silicates. The pH values showed an irregular pattern with highest values observed in the spring months. Total dissolved solids (TDS), Ca, Mg and HCO_3 are primarily related to leaching and evaporation, with elevated levels that occurred in the winter months. In contrast, seasonal patterns in Na, K, Cl, and NH4–N contents showed decreased values in wet months. Peaks in NO_3–N observed in winter are strongly associated with agricultural runoff. Changes in chlorophyll-a level were coincided with low ratio of TN to TP. BOD_5 and COD peaks in spring corresponding with high algal growth. No significant changes in most of physical and biochemical parameters with depth, probably due to shallow depth, high annual sedimentation rate and heavy pumping rate in dry months. No available recorded data for long-term monitoring of Sharhabiel reservoir water to emphasize the self-purification capacity of dam.

Key words: Sharhabiel Dam, Nutrients, Physiochemical, Parameters-Jordan.

INTRODUCTION

Water quality monitoring for the detection of trends, impacts, and improvements is further complicated because the issues of concern and available resources are constantly changing (Hirsch *et al.*, 2006). Jordan is one of the poorest countries in the MENA region in all types of natural resources, especially water. At the same time, Jordan is one of the fastest growing countries in population due to the high population growth rates combined with a rising erratic number of migrants and refuges from the different surrounding counties. The latest wage of refuges influx from Syria is expected to mount the pressure on ensuring the already limited water quantities in acceptable water quality. Hence, water reservoirs play an essential role in Jordan's water strategy especially for irrigation purposes (Saadoun, *et al.*, 2008).

Increased erosion due to high winter runoff combined with higher water temperatures and more prolonged stratification in summer will, almost certainly, lead to widespread, climate-related eutrophication (Dokulil and Herzig 2009). Increased soil erosion and runoff will enhance nutrient load particularly from nitrogen and phosphorus to reservoir lakes.

Nutrients, such as nitrogen, phosphorus, and silicate, in reservoirs are prerequisites for life and do not form an environmental problem. Sediments of surface water runoff from the surrounding land continue to supply organic nutrients and minerals to the Jordanian reservoir ecosystems. Atmospheric input from Mediterranean Sea as wind borne microorganisms is another source of the food base for growing larger plants and animals in addition to that human activities can also accelerate the rate at which nutrients enter Jordanian reservoir lakes. Two major nutrients are necessary for the development of aquatic life, namely nitrogen (N) and phosphorus (P), a third one, namely silicate is necessary for the development of diatoms (Rhee 1982).

Knowledge of the nutrient loading rates can shed some light on the potential productivity of the reservoir. In water affected by human made effluents, such as that of Shurhabiel Reservoir, high primary production resulting from an excessive load of nutrients may cause problems affecting water quality. Phytoplankton and nutrient dynamics are closely linked since nutrient uptake during algal growth is the main process which removes dissolved nutrients from the water. Shurhabiel reservoir is one of the major water resources in NW Jordan. Shurhabiel reservoir receives untreated waste water (Abu- Rukaha 2004; El-Radaideh *et al.*, 2014). Monitoring the quality of surface water in Jordan is very important because the reservoirs are essential sources for drinking water and other domestic and agricultural activities (Fandi *et al.*, 2009). The present study aimed at investigating physiochemical and biological parameters which prevailed in Shurhabiel Reservoir over the year 2013. This can help decision-makers to put best solutions into practice.

Catchment area and dam site setting

The catchment's area is covered by limestone, marle and dolomite of Ajlun and Belqa group of upper Cretaceous age (Bender, 1974). It generally consists of steeply graded hillsides with the drainages in deeply incised valleys. The upper parts of the catchment area (located in Ajlun highs) have a maximum elevation of +1050 m a.s.l with a natural forest cover and rich in loamy soil. They are dominated by a semi humid - humid climate with excess water during winter season. The lower part of the catchment area (located in Jordan River) is dominated by an arid climate characterized by a high temperature and an increase in evapotranspiration rate during summer. The yearly value for mean rainfall, mean annual runoff and flood runoff are 512.1 mm, 13.04 MCM and (9.6% -10%) respectively (Water Authority, 1989). The western part (Jordan River) is dominated by arid climate, with an annual rainfall of only 300 mm/yr. Potential evaporation ranges from 2050 mm/yr in the west to 2200 mm/yr in the east.

Sharhabiel Reservoir was constructed in 1966; it is a rock fill dam, 48 m in height, located on ZeglabWadi in the northwest side of Jordan, (Fig.1). The dam has a spillway, which is a side overflow weir without a channel. The spillway crest elevation is 86m below mean sea level. The water level was 94m (spring 2013) below mean sea level. The deepest point recorded was 112 meters below mean sea level. It is evident that the slope of the bed of the reservoir gradually drops down in elevation from the east toward the west where the Sharhabiel Dam is situated. The deepest area lies directly east of the dam. The average annual sediment accumulation rate of 0.046 MCM. The dam drains a catchment area of 106 square kilometers (Shatnawi, 2002) and at construction had a maximum storage capacity of 4.4 MCM (Arger, 1997; Macdonald, 1965a). Land use is agrarian with natural forests and a medium human population density.

The maximum length of the reservoir is 1500 m extending west–east with a width ranging between 35 and 500 m (Shatnawi 2002). A number of springs debouche along Ziqlab wadi with an annual discharge of about 5 MCM (Arger, 1997). In addition, Ziqlab wadi drains another 5 MCM/yr of floodwater (WAJ 1989). Ziqlab wadi is fed by a number of small tributaries such as Wadiat-Taiyiba and Wadi Abu Ziyad from the north and south, respectively, where slopes are steeper (El-Radaideh *et al.*, 2014), (Fig. 1). The water discharged into the reservoir from the east by Ziqlab wadi, its semi muddy in the rainy storm events. The wadi flows in a steep sided valley and has an average gradient of 50 m/km with two distinct series of falls 120 m and 30 m high respectively. The valley widens out into the Ghor (graben) at an elevation of –175 m. Field study shows, other surface materials in the southern Sharhabiel Reservoir area, consisting of fluvial, alluvial, and organic deposits, are generally stratified and moderately well sorted. Outwash materials consist mainly of rounded gravels mixed with sand and silt, such deposits usually occur at the lower portion of Ziqlab wadi catchment. According to JVA, (1965), the geological succession in the dam area can be described as a talus, alluvium, cap conglomerates with crystalline and oolitic/pisolitic limestone, red pebbly and sandy marls, lenticular calcareous conglomerates, crystalline limestone with some marlstones, glauconitic calcareous sandstone's, and chalk. The cap rocks which belong to the Plateau gravel group overlie the lower formation unconformable. The chalk and overlying formations appear conformable but a disconformity may exist however, as there is a marked change in lithology. The chalk is considered to belong to the upper white chalk member of the Belqa group (Fig.1).

MATERIALS AND METHODS

This study relies depends on 12 monthly surveys and findings from literatures (El-Radaideh *et al*., 2014) and data were obtained from the (JVA) Jordan Valley Authority to evaluate water quality in the Sharhabiel Dam. Two sampling sites (A1 and A2) were selected for investigation. A1 was closer to the shore of the reservoir lake and A2 represents the open area and the deepest point at the reservoir bed (Al-Ansari and Shatnawi, 20[illegible]) with water depth more than 16 m, about 200 m from site A1, (Fig. 1). The one-year monitoring data (2013) include the following:

- Field measurements of water temperature, pH, salinity, dissolved oxygen and conductivity were measured in situ with water transparency using a Secchi disc (21 cm) at each site and by using a multiparameter portable instrument (WTW, Multiline F / SET-3).
- In order to investigate the vertical distribution of some of the changeable parameters under consideration, deeper samples at site A2 were collected at two meters interval. Surface water samples were collected in pre-cleaned polyethylene containers and transported to the laboratory in an ice-filled box for analysis. Samples were then refrigerated at 4 °C and analyzed within 48 h of sampling; water sampling and preservation were carried out according to APHA, (1998). Samples for chemical analysis of nitrate, phosphorous and silicate were filtered using Whatman millipore filters with 0.45 ìm pore size. Alkalinity was determined following the Standard Methods (APHA 1998). Surface water samples were also analyzed for Na and K (by flame photometer); Ca and Mg (by titration method); HCO_3, (by ion chromatography); COD (by closed reflux, titrimetric method); and chlorophyll-a (by fluorometric determination). Samples were analyzed in duplicates with analytical uncertainty of less than 5 %.

RESULTS AND DISCUSSION

Fluctuation of water levels at Sharhabiel reservoir is the combined result of irregular inflow and outflow. According MWI (2009) water level of Shahabiel Reservoir showed a decreasing trend from spring through summer, with lowest levels that were measured in the dry summer months. These low levels of the reservoir water in the summer months are primary attributed to increased consumption of water for irrigation use and to high evaporation rate during the dry months. The water-level oscillation contributes to marginal erosion and sedimentation in the reservoir (HKJ-GTZ 2009; Branco *et al.* 2002) with potential release of nutrients and trace metals from sediments, usually during flood events, (Zhao *et al.* 2013; Fonsica *et al.*, 2011). A wide fluctuation in water level, however, is a common feature in reservoir and affects their ecology through, an enhanced nutrient exchange between pelagic and littoral zones of the reservoir (Fonsica *et al.*, 1993; 2010).

Physical Monitoring

Temperature

Slight variation in surface water temperature between sampling site A1 and A2 can be attributed to the time of sampling (Fig.1, and Fig. 2, a). A mean air temperature of 28.2°C with a maximum of 39.5°C in July and minimum of 15°C in February, 2013 are consistent with the fact that the reservoir is situated in a Mediterranean subtropical to temperate climate. Owing to the rapid increase in air temperature in July a slight short thermal stratification developed in the reservoir and lasted until August (Fig 2, b). In addition to increasing the amount of solar radiation reaching the reservoir water's surface, removal of vegetation near dam and its catchment streams often results in increased erosion and increased amounts of sediments in the dam. The sediments absorb heat from sunlight rather than reflect it. This heats the water further.

Vertical gradients in temperature can be measured in deeper and shallower water systems, in May 2013, very weak thermal stratification was observed with an average of 2.5°C temperature difference recorded between surface and deeper layers (Fig. 2, b). More clear stratification developed in June 2013, with an average of 4.0°C difference in temperature between surface and underlying water. Two layers of distinctive temperatures were recognized: the surface layer, 10 meters deep with an average temperature of 32°C, and a second layer down to 16 meters depth with an average temperature of 28.7°C (Fig. 2, b). This slight stratification continued in July with an average of 3.40°C difference between the two layers.

The average difference in water temperature between surface water and the deepest point measured (16 m) at site A2 was 4[illegible] and 3.40°C in June and July respectively, a difference which insured the presence of a weak thermocline between the upper layer and the lower layer (Fig. 3, b). The thermocline, however, was broken in August because of a change in water temperature, and due to an excessive pumping of water from the reservoir which remarkably reduced water depth. Sharhabiel reservoir can be considered monomictic where weak thermal stratification occurs once a year

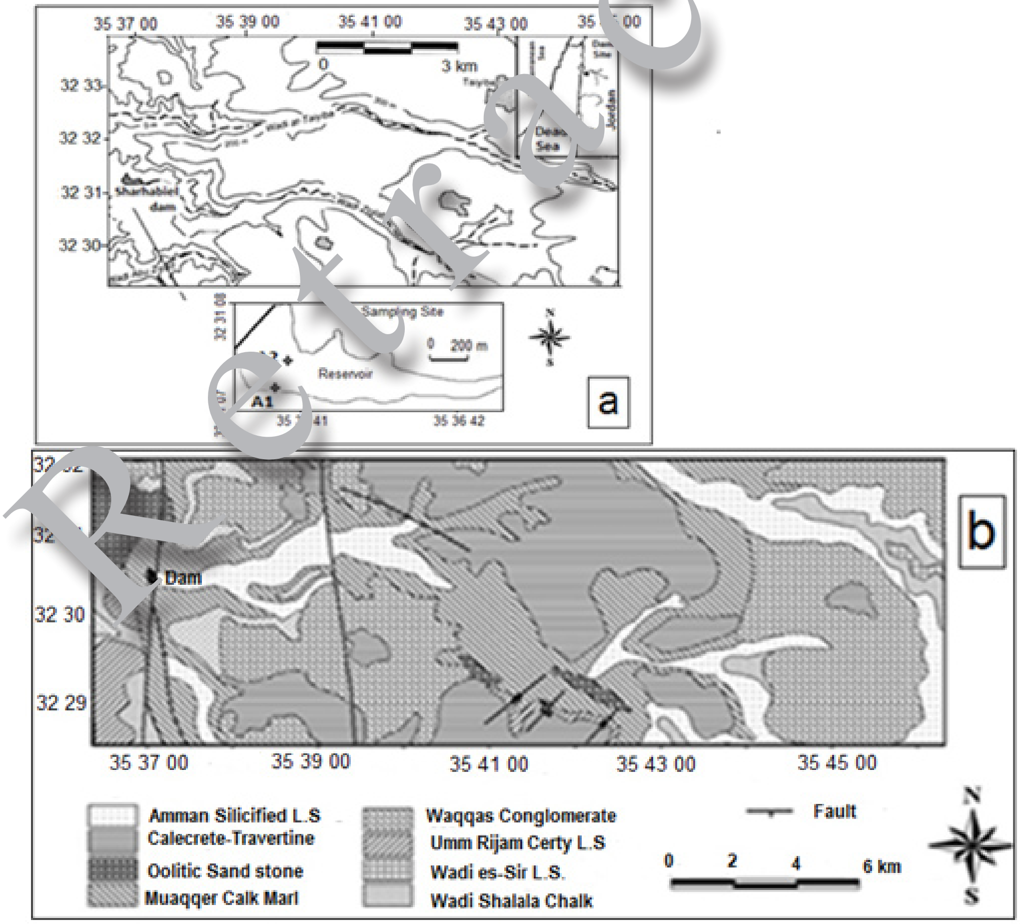

Fig.1: (a): Map of the study area with location of sampling points (A1 and A2) in Sharhabiel Reservoir. (b): Geologic map of the study area.

during summer. Thermal stratification, however, is a common phenomenon in MENA regions. Similar water layering was recorded in King Talal reservoir and Wadi Al-Arab Dam in Jordan (Al-Handal & Saadoun 2001, Saadoun *et al*., 2010). Similar conditions can also be observed in reservoirs located in subtropical and temperate regions (Temponeras *et al.* 2000). Temperature gradients are set up due to the physical properties of water , where water is most dense at 16 m depth, ensuring that cooler waters will typically be found at the bottom of reservoir lake.

Temperature is important in aquatic reservoir because it can cause mortality and it can influence the solubility of dissolved oxygen (DO) and other materials in the water col umn. Photo inhibition due to the increase in the photoperiod in summer may lead to a marked decrease in chlorophyll-a content of the reservoir (Fig.3, a), while in winter when light is weak and daylight is short, the role of temperature on primary production was insignificant.

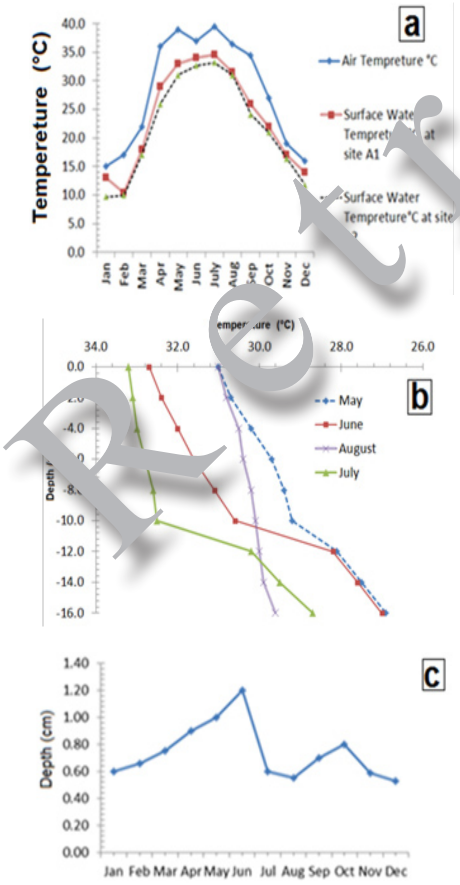

Fig. 2: (a) Air -water temperature, (b) Depth temperature profiles and (c) Water transparency at Sharhabiel Reservoir.

Water Transparency

Water transparency in the reservoir was relatively low during the study period. The minimum Secchi depth coincided with surface algal production in December 2013, which characterized by an increase in the phytoplankton biomass. The maximum secchi depth in June reflects the low phytoplankton density. The mean Secchi disc depth of 0.74 m may explain the water turbidity in the reservoir that is derived from suspended phytoplankton, and partially from total suspended solids, which were kept at a minimum due to weak mixing and decreased water inflow (Fig.2, c).

Biochemical Monitoring

Dissolved Oxygen Levels

Water temperature had a remarkable effect on dissolved oxygen concentration in the Shrhabiel reservoir. Dissolved oxygen levels ranged from 6.05 to 8.7 mg $^{-1}$l at site A2 , while the maximum value at site A1 was 8.8 mg $^{-1}$l with overall mean DO values at site A2 more than site A1 (Fig. 4,a).

The lowest DO values at both sites were in August 2013 (6.05 and 6.1 mg l^{-1}at site A2 and A1, respectively). In February, DO peaks during winter season at station site A2, as shown in figure 4, a. DO concentration diminished with depth from April through August. In April, dissolved oxygen concentration dropped from 7.8 mg l^{-1}at the surface to 4.1 mg l^{-1} at 16 m depth. In May, DO in the upper layer was 7.36 mg l^{-1} then dropped to 4.44 mg l^{-1} in the deepest water layer (Fig. 4, b).

Chlorophyll-a - Nutrients

P-PO$_4$ mean level at site A2 was 0.54 mg $^{-1}$l and at site A1 as 0.35 mg $^{-1}$l, with minimum values of 0.16 mg $^{-1}$l recorded in October at both sites. Levels of P-PO$_4$ were high; with maximum concentrations of 1.1 mg l^{-1} and 0.8 mg l^{-1} found in June and May at sits A2 and A1, respectively (Fig.3,b). Concentrations of phosphorus in water are quite low; dissolved orthophosphate concentrations are usually not greater than 5 to 20µg $^{-1}$1 and seldom exceed 100 µg^{-1} l even in highly eutrophic waters, whereas the concentration of total phosphorus seldom exceeds 1000 µg $^{-1}$l (Boyd 1976, Boyd 1990).

In discussing the correlation of different parameters with primary production, chlorophyll-a appears to be the closest factor in this regard and is widely used as an indirect measure of phytoplankton productivity (Voros and Padisak, 1991). Chlorophyll-a level can be an effective measure of trophic status and potential indicator of maximum photosynthetic rate and are a commonly used as a measure of water quality. It is an indicator of algal biomass (Forsberg & Ryding1980; Cloot & Ros1996) which is largely dependent on TP in freshwater (Dillon & Rigler1974; Pridmore *et al*. 1985; Guildford *et al.* 1994). In lake level of phosphorous greater than 0.02 mg^{-1}l can stimulate the growth of most types of green and blue green algae (Wetzel 1983). Chlorophyll-concentrations are seasonally high, suggesting phytoplankton blooms throughout the monitoring period. However moderate correlation coefficient between chlorophyll-a and TP levels (r=0.45; Table1). Dodds (2003, 2006) indicated that TN-TP ratios are more accurate indicators of nutrient limitation. Fluctuations in chlorophyll-a level was closely tied to TN-TP ratio (Fig.4, a).

Excessive growth of algae (high chlorophyll-a level) has nearly coincided with a low ratio of TN-TP (Fig. 3, a). This indicates that chlorophyll-a is more strongly related to TP than to TN, and that phosphorus is generally the limiting factor for algal growth. Seasonal reduction of algal growth, when TN-TP is still low, indicates that nutrients may not be the only variables regulating algae growth in the reservoir, but also light, temperature, low CO$_{2,}$ high pH and low turbidity may promote cyanobacteria

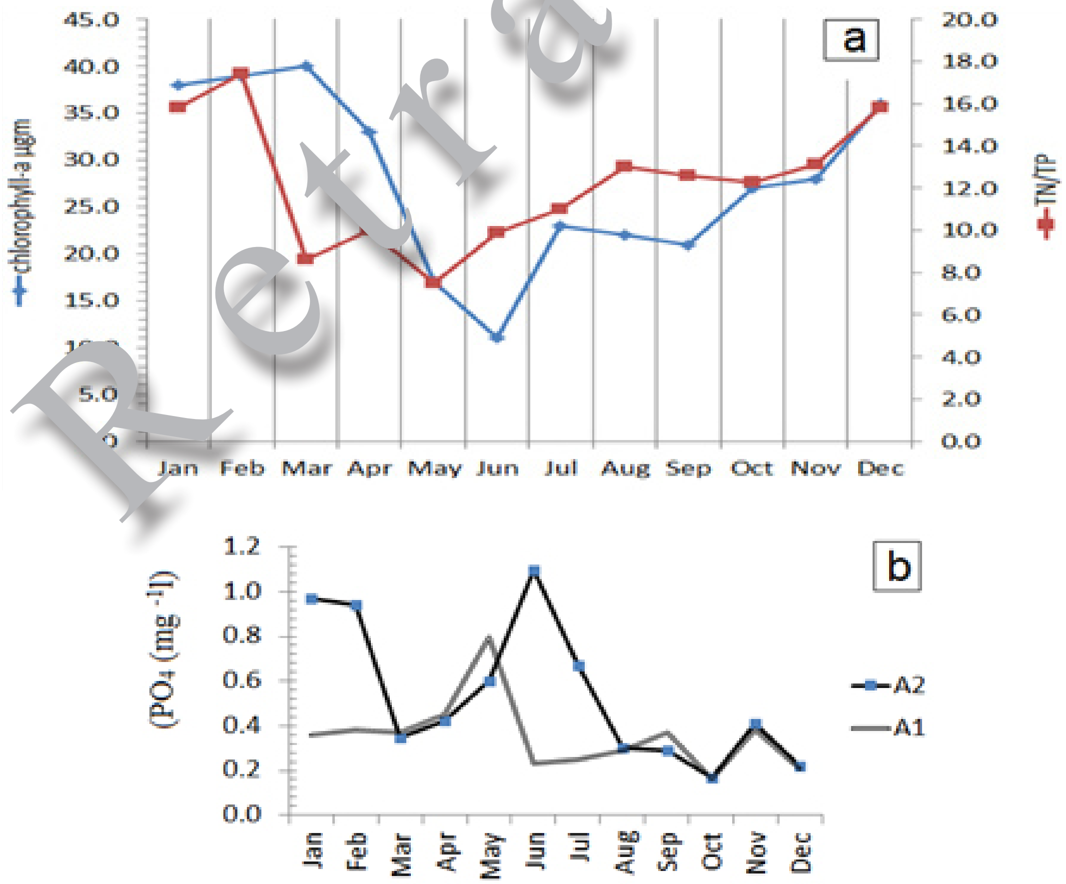

Fig.3: (a) Monthly variations in chlorophyll-a level with TN-TP ratio, (b) phosphorus (PO$_4$ (mg $^{-1}$l) concentration at sites A1 and A2

growth (Levine & Schindler1999). Higher phosphorus concentrations were particularly corresponded to spring with months of most active microbial and algal growth. Nonpoint source pollutions are a major source of phosphorus to Sharhabiel dam water; phosphorus can potentially be released from the dam sediments through biological and chemical processes and mixed into the water column. (Madison1994; Fonsica 2011), very fine sediment (less than 63 ìm) is often chemically active. Phosphorus and metals tend to be highly attracted to the ionic exchange sites associated with iron and manganese positive relationship between suspended solids in water bodies and total phosphorus concentrations is demonstrated by Ongley (1996). Many toxic organic contaminants are strongly associated with silt, clay and organic materials transported by water to reservoirs (Boatman *et al.*, 1999; Owens *et al.*, 2005). Thus, sediments act as an agent in the process of eutrophication and toxicity in aquatic organisms.

Phosphorus is also leached from phosphate bearing strata of Amman silicified limestone

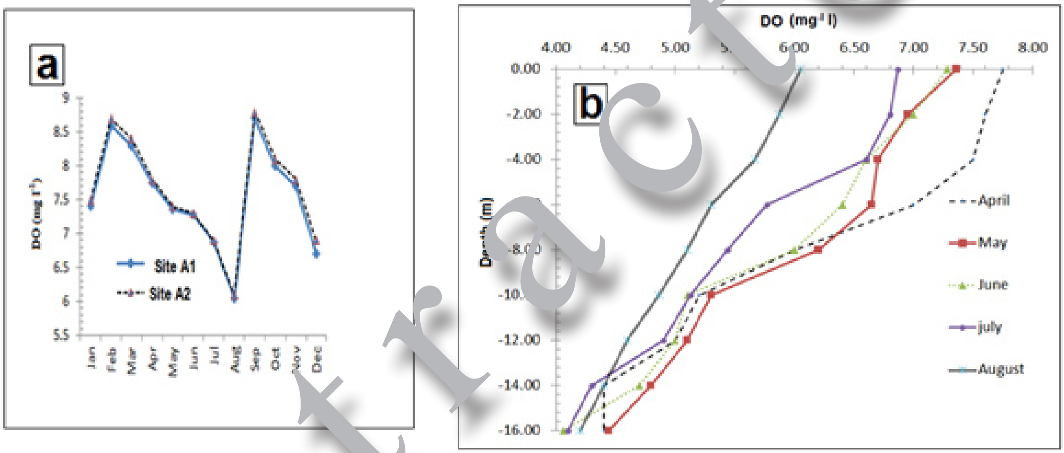

Fig. 4: (a) Water dissolved oxygen in mg $^{-1}$l at sites A1 and A2 (b) Depth profiles of water dissolved oxygen in mg $^{-1}$l (April, May, June, July and August)

Table 1: Correlation matrices between water quality parameters of Sharhabiel Dam

	pH	TDS (mg^{-1}l)	Ca (mg^{-1}l)	Mg (mg^{-1}l)	Na (mg^{-1}l)	K (mg^{-1}l)	Cl (mg^{-1}l)	HCO_3 (mg^{-1}l)	Total P (mg^{-1}l)	NO_3 (mg^{-1}l)	NH_4-H (mg^{-1}l)	BOD5 (mg^{-1}l)	COD (mg^{-1}l)
TDS	0.08												
Ca	-0.09	0.85											
Mg	-0.59	0.27	0.66										
Na	-0.57	0.06	0.50	0.95									
K	-0.47	0.08	0.49	0.94	0.93								
Cl	-0.41	0.10	0.54	0.94	0.96	0.98							
HCO_3	0.00	0.81	0.89	0.59	0.40	0.52	0.52						
Total P	0.41	0.13	0.00	-0.14	-0.31	0.04	-0.06	0.35					
NO_3-H	-0.47	0.55	0.74	0.78	0.71	0.68	0.68	0.73	-0.07				
NH_4-H	-0.32	-0.91	-0.65	0.04	0.27	0.17	0.17	-0.67	-0.39	-0.28			
BOD_5	0.65	-0.47	-0.74	-0.90	-0.83	-0.74	-0.74	-0.58	0.36	-0.83	0.13		
COD	0.74	-0.35	-0.59	-0.78	-0.75	-0.56	-0.58	-0.33	0.63	-0.68	-0.02	0.94	
chloro-phyll-a	-0.15	0.53	0.68	0.63	0.46	0.60	0.56	0.74	0.45	0.61	-0.43	-0.49	-0.30

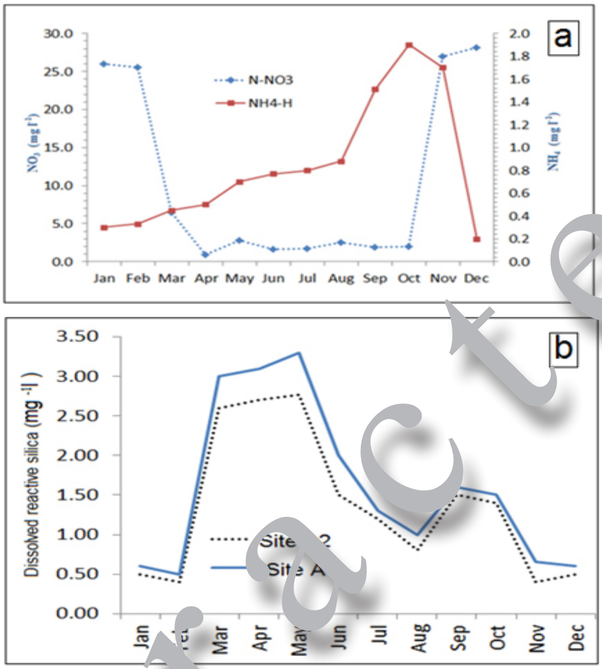

Fig. 5: (a) Distribution of NO_3-N and NH4-N concentrations of Sharhabiel Dam water during the study period (b) Silicate (Si) (mg l^{-1}) concentration at sites A1 and A2

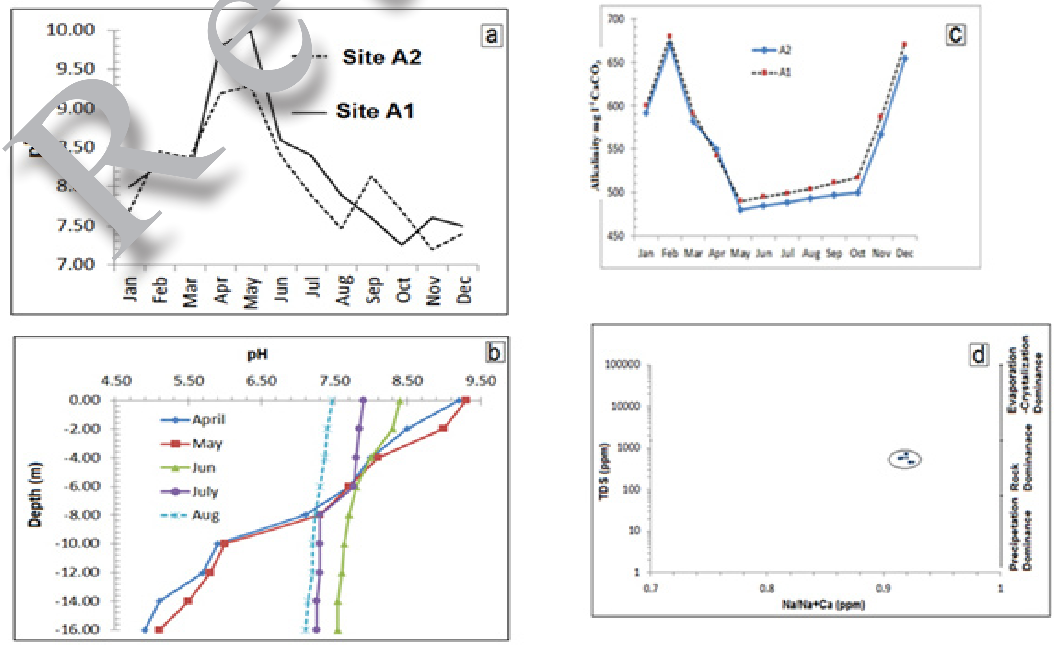

Fig. 6: (a) pH at sites A2 and A1 (b) Depth profiles of pH-April, May and June (c) Alkalinity in mg^{-1}l $CaCO_3$ and (d) Plot of Sharhabiel Dam waters on Gibbs diagram

Formation outcrops in the upper catchment (Fig.1). Other major sources of phosphorous are fertilizers and pesticides carried in agricultural discharge from the upper catchment soils. Phosphorus can enter freshwater from atmospheric precipitation (Wetzel, 2001; Soares *et al*., 2008). Based on chlorophyll-a classification of Forsberg& Ryding (1980), Shrahabiel Reservoir is in a eutrophic to hypereutrophic condition. Trophic status of Sharhabiel dam water with regards to total phosphorus concentration is in hypereutrophic; where total phosphorus concentration (0.35 mg^{-1}l) was more than 100 µg^{-1}l . Based on the studies carried by Yang *et al*. 2008; Richardson *et al*. 2007; Cheng and Li 2006, the reservoir is excessively eutrophic because the mean of TP concentrations throughout the year 2113 is 0.353 mg $^{-1}$l greater than 0.3 mg $^{-1}$l. Eutrophication has been reported in lake water when TP is greater than 0.3 mg $^{-1}$l or even at lower TP concentrations. Field observations indicate that the reservoir has been excessively eutrophic.

The average TSI (Trophic Status Index), (Carlson 1977) values ranged between 70 (in fall) to 80 (in spring), also indicating that the reservoir is excessive-eutrophic (Ferrier *et al*., 2001).

Mean reservoir N-NO_3 for both sites is 10.9 mg $^{-1}$l N, with minimum and maximum concentrations of 1.0 mg $^{-1}$l N and 31.3 mg $^{-1}$l N, at site A1. Which are higher than average content of most aquatic ponds 2.5 to 500 µg $^{-l\ 1}$ (Boyd 1976). Nitrate-N concentrations increased remarkably during the wet months, with a remarkable rise were observed in November to February at both sites (Fig.5, a, b), where the concentrations decreased to approach its minimum values in the summer and fall mouths. Nitrate is closely linked to agricultural runoff (Ferrier *et al*. 2001). More than 20% of the catchment lands are used extensively for agricultural purposes and the increase in NO_3–N concentrations may be due to leaching from NO_3 fertilizers. High-intensity rainfall generally mobilizes more nutrient-laden sediment than low-intensity storm events (Basnyat *et al*.20[illegible]).

NO_3-N enters Sharhabiel Dam probably from surface runoff and is removed either by algal

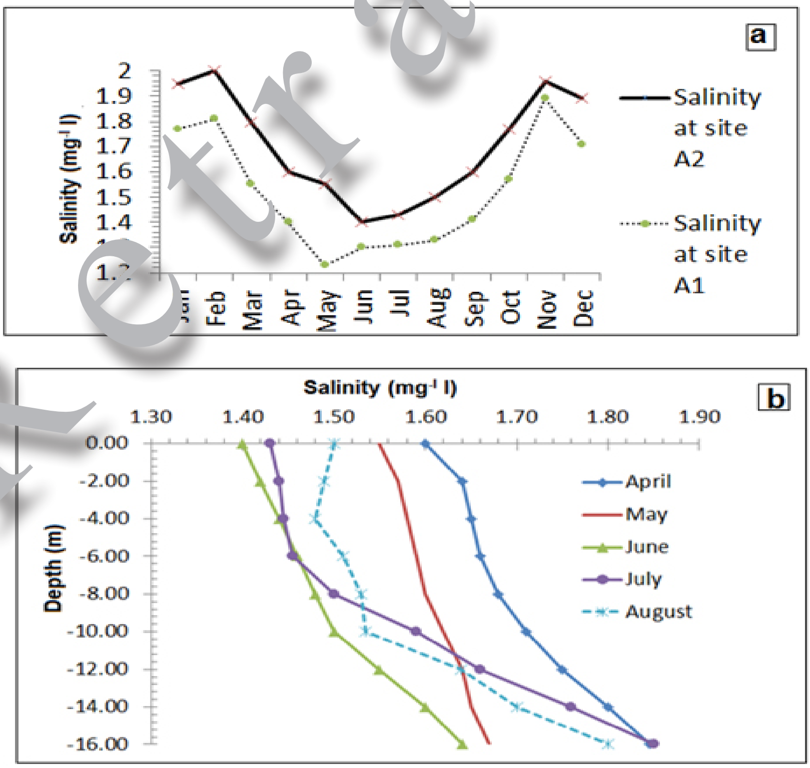

Fig.7: (a) Salinity at sites A2 and A1, (b) Depth profiles of salinity: April May, June, July and

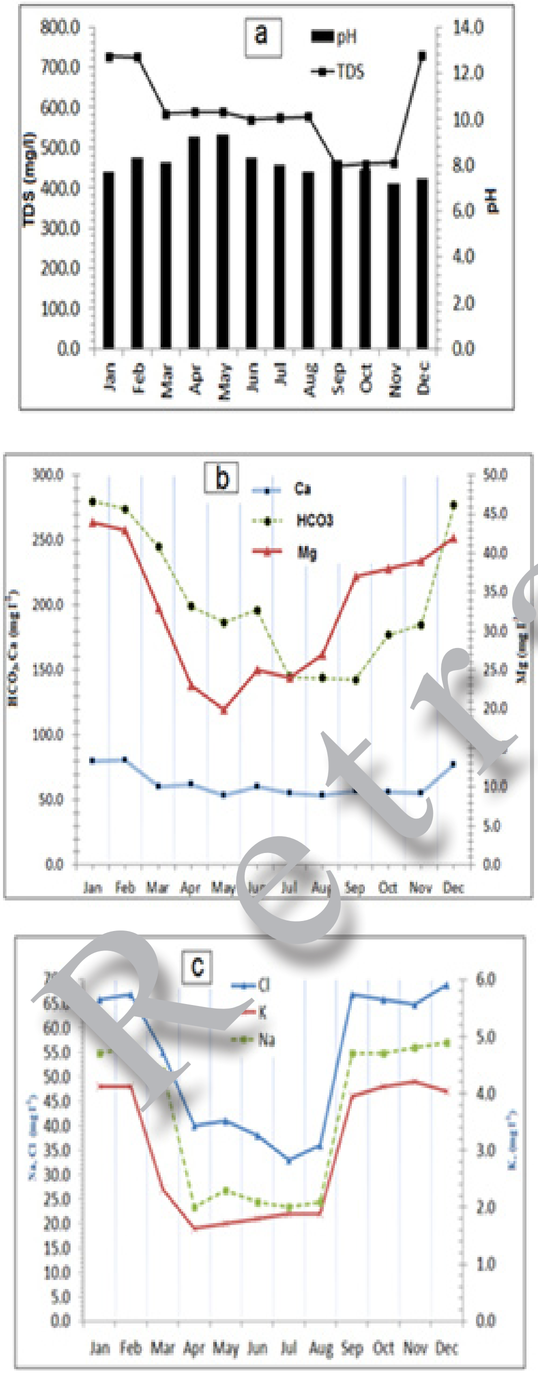

Fig. 8: (a) Monthly distribution of pH and TDS values in Sharhabiel Reservoir during the monitoring period(b) Fluctuations in Ca, Mg, and HCO_3 levels of Sharhabiel Dam water during the study period (c) Fluctuations in Na, K, and Cl concentration of Sharhabiel Dam water during the study period

uptake and sedimentation or through denitrification. Other sources of nitrate include animal waste, inputs from sewage, soil erosion, and domestic waste from cesspools and fertilizer runoff from planted crops. In addition, the submergence of a large area containing a large amount of plants and soils following high rainfall may also contribute to the higher NO_3–N concentrations (Gaudet & Muthuri 1981). This is consistent with observations that elevated values occurring in winter were corresponded with high rainfall and runoff containing nitrate from adjacent agricultural land. Also, the relative high levels of nitrate are often associated with spring months because of nitrogen fixation microbes. Decay of organic residues and decreased temperature (which reduces nitrogen fixation process) is other contributing causes to lower nitrate contents in the fall and summer seasons.

Negative correlation was observed between NO_3–N and TP (r= -0.07) suggesting that different sources of these nutrients. In contrast to NO_3–N, NH_4–N concentrations are lowest in winters and highest in fall (Fig.5, b) consistent with the negative correlation observed between both ions (r= " 0.28; Table1). This suggests that NH4–N is not probably associated with agricultural runoff and winter leaching. The decreased concentration of NH4–H in summer months is possibly attributed to the effect of higher temperature range during dry months, which led to increased NH4–N volatilization and to reservoir water dilution in wet months (Duyzer *et al.*19).

Levels of DRS at the reservoir showed low values with a mean concentration of 1.36 mg $^{-1}$l and 1.6 mg $^{-1}$l at sit A2 and A1, respectively (Fig. 5,b). Dissolved reactive silica could be attributed to chemical weathering of igneous rock on the country side areas (Abu Raka, 2004) and may probably to extensive fires of dry grasses and crop remains during summer at the eastern lands of Israel that carried by western wind and as minute input air sole . Additional possible sources of silica are the product of chemical weathering of minor oil shale and lensoidal beds of clay stone outcrops belongs to chalk marl formation (Fig.1).

pH

The pH surface values did not show clear seasonally variations through the study period (mean

8.3 and 8.1at sampling sites A1and A2, respectively). Between January and June, pH values were higher than 7.7 with maximum and minimum surface pH of 10.0 and 9.3 recorded in April and May 2013 at sampling site A1 and A2, (Fig.6, a).

While winter months shows lowering in pH values due to stream floods containing large quantities of a dissolved basic ions are discharged into the reservoir, as a result of intense chemical weathering of carbonaceous formations of the upper Sharhabiel catchment (Ajun Highs), (Fig.1). The relative low levels of pH observed in the winter months are probably attributed to decreased photosynthetic rates in response to lower temperature and decreased in sunlight duration and intensity. According to Soares *et al*. (2008) the higher rate of phytoplankton growth is more likely associated with highly duration and intensity of light. In addition to the dilution effect of a large volume of water flowing into the Shrhabiel dam from upstream in winter season which is highly rich in ammonium fertilizers, decaying of plant and organic fragments could be decreased the water pH values (Gaudet & Muthuri 1981). Relatively high water pH levels observed, particularly in dry months, are primarily related to increasing in phytoplankton growth, high temperature, sunlight intensity and nutrient availability. According to Fonsica *et al*., (2010; 2011) and Kelly (2009), very high pH values would dissolve and release metallic micronutrients, macronutrients, salts and ammonia from reservoir sediment which led also to increasing pH values. Dominance of cyanophytes in summer was shown to be favored at high pH, possibly because of the ability to use the bicarbonate ion as a carbon source (JVA, 2010). Due to the high plumbing rate and absence of water inflow in summer, neutralization of the water pH has no role in the reservoir.

The water column during the monitoring year showed homogeneity with no differences in pH readings, except in April and May months, pH values showed a minor variation with depth. However, an average difference of 3.7 in pH value was recorded between surface and deeper water (Fig. 6, b). The low pH values in the deeper water of the reservoir can be attributed to the shallowness accompanied by the high rate of sedimentation 0.041 m^3/y (Al-Ansari 2010) and the metabolic activities of the microorganisms in the sediment.

Solutes

The levels of salinity, TDS and alkalinity, also seasonally fluctuated over the 12-mounth study period, where highest values were generally corresponded with wet months and lowest values corresponded with dry months

Salinity did not vary with depth even during the minor thermal stratification; salinity showed no pattern of variation, this might be attributed to the relatively shallow depth of the dam. Very little difference was recorded during the course of the year. The average concentration of salt was 1.61 mg l^{-1} at both sites (A2 and A1). The highest salinity was recorded in February at site A2 where it reached 2.00 mg^{-1} l, which coincided with an increase in the

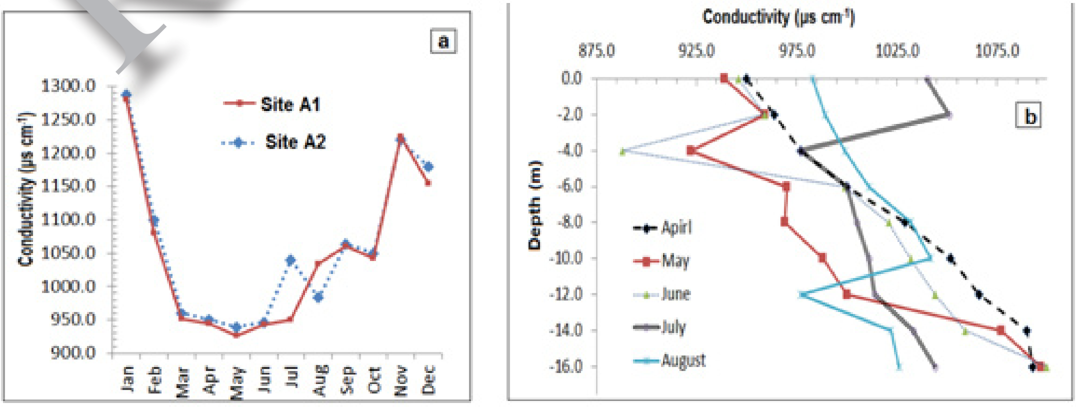

Fig.9: (a) Conductivity at sites A2 and A1, (b) Depth profiles of conductivity: April May, June, July and August

reservoir inflow. At site A1, salinity was rather higher with a maximum value of 1.89 mg l^{-1} in November (Fig. 7, a, b).

The source of dissolved salts in the reservoir water seems to be mainly weathering of rocks, Na/ (Na + Ca) plotted against TDS according to Gibbs (1970), demonstrated rock weathering as a dominant process (Fig.6, d), this agree with result of (Abu Ruka 2004).

Intense chemical weathering of the adjacent dam site carbonate rocks (limestone, dolostone, chalky marly limestone and silicified limestone) in response to high winter rainfall and runoff is the primary contributor to high TDS, alkalinity, and salinity values. Dry months shows lowering in TDS, alkalinity, and salinity values compared to that of other months are attributed to high rate of evaporation. Water evaporation in the reservoir accelerates mineral precipitation and reduces TDS levels (Fig.6, c and Fig. 7, a, b).

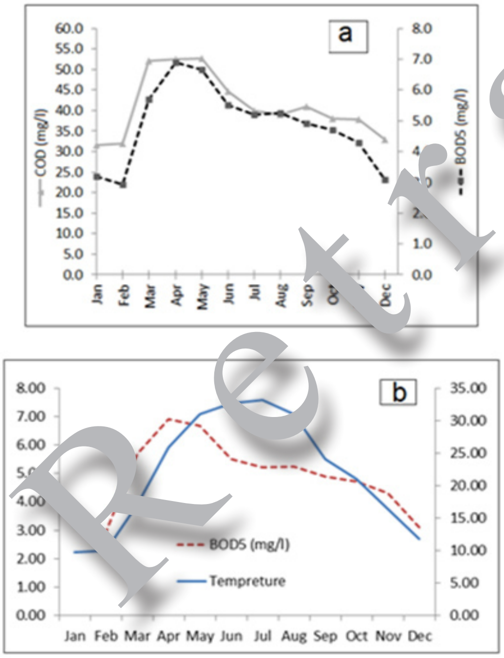

Fig. 10: (a) Monthly distribution of COD and BOD_5 values in Sharhabiel Reservoir during the monitoring period (b) Relation between BOD_5 and temperature values of Sharhabiel Dam water during the study period

Slight variations in TDS levels between wet and dry months were found, in 2013 (Fig.8, a), the increase in water use for irrigation would increase turbidity levels and enhance re-suspension of settled particles and subsequent dissolution of precipitated salts. However, the higher rate of evaporation in summer is the probable cause for the lower TDS compared to that in winter.

Similar to TDS, the concentrations of Ca, Mg, and HCO_3 in the reservoir water are primarily linked to leaching and evaporation (Fig. 8, b). Relative to dry season, elevated levels of Ca, Mg, and HCO_3 were observed in winter periods in response to leaching and decreased concurrent with the drier months.

The lower values measured in dry months are attributed to precipitation of carbonate minerals following an increase in temperatures and evaporation. The similar distribution patterns in Ca, Mg, and HCO_3 suggest that these ions are probably originated from similar sources (Abu Rake 2004, El- Radaideh 2014). Ca is positively correlated with Mg, HCO_3, and TDS with r=0.66, 0.89, and 0.85, respectively (Table1), and believed to have been derived from calcareous formations; these formations cover a significant portion of upper Wadi Ziqlab watershed area (Fig.1). In addition, Ca concentrations showed positive correlation with PO4 (r=0.40; Table1) suggesting that phosphorite minerals (from phosphate-bearing strata which belong to ASL Formation) is another source of both Ca and P. The distribution patterns in Ca, Mg, HCO_3 and TDS show that they constitute a major poron of TDS in water. This is evident from the positively correlation coefficients between TDS and Ca, Mg, and HCO_3 (r=0.85; r=0.40; r=0.81; Table1)

In contrast to Ca, Mg, HCO_3, and TDS, monthly patterns in Na, K, and Cl contents of surface water of Sharhabiel dam also showed higher values in wet periods (Fig. 8, c).

During the winter seasons, their concentrations increased, and during warm water months, the concentrations fluctuate, but stay consistently lesser than that of the cold water months. These high levels that occurred in winter are likely attributed to slightly unmixing process following heavy rainfall with the reservoir water.

In addition, the relative highest levels observed in fall months are related to precipitation of carbonate minerals and subsequent prevalence of Na, K, and Cl salts. Na and Cl concentrations are positively correlated (r=0.96) indicating that they were derived from a similar source (halite). Halite dissolution releases equal concentrations of Na and Cl, but data showed deviations from 1:1 relation indicating that a fraction of Na is associated with anions other than Cl. The average Na/Cl molar ratio (of about 1.25) suggests that Na may have also been released from silicate-weathering and dissolution reactions (Meybeck 1987, Abu Ruka 2004). Weathering of N -plagioclase (the igneous rocks in the surrounding area) is a potential contributor of Na in water.

While both Na and Cl showed similar monthly distributions to that of K, they are negatively correlated with K (Table1). The correlation coefficient between Na and K is highly positive (r= 0.93) suggesting similar possible sources for both ions. The possible source of k ions, seem to be chemical weathering of k-feldspar and atmospheric input from Dead Sea aerosol salts, particularly sylvite particles.

The relative low K concentrations in Sharhabiel Dam water is probably attributed to adsorption by clay particles and formation of secondary minerals (Matthess 1982). In addition, the strong positive correlation between K and other major ions like NO_3-N, (r= 0.68) (Table1) suggests that K was probably derived from agricultural fertilizers (Batayneh *et al.* 2008).

Samples of site A2 showing slightly higher values of total alkalinity and ranged between 490 mg l^{-1} $CaCO_3$ and 680 mg l^{-1} $CaCO_3$ in May and February, respectively At site A1 the minimum total alkalinity of 480 mg l^{-1} $CaCO_3$ and a maximum of 671 mg l^{-1} $CaCO_3$ were recorded in May and February, respectively. Total alkalinity showed relatively higher values throughout the study year with an average of 552 mg l^{-1} $CaCO_3$. The two sites showed increasing levels of alkalinity during the wet season from October to March (Fig.6, c)

The mean alkalinity of the reservoir was 552.0 as mg $^{-1}$l $CaCO_3$, which highly correlates with salinity and conductivity (r= 0.86; r= 0.60). This result agreed with previous work in Wadi Al-Arab Dam reservoir (Saadoun *et al*., 2008, 2010). The ratio of total alkalinity: conductivity of 0.53 established at the reservoir is in close agreement with a ratio of 0.50 computed by Kotut *et al*. (1999) for a number of MENA reservoirs. Levels of alkalinity showed an increase in the wet season in comparison to the dry season due to engagements of catchment soil through erosion from Ziqlab wadi and their tributaries.

Conductivity values in the reservoir were generally high; with a total mean of 1054.6 ìS cm^{-1} and no pattern of periodicity (Fig. 9, a).

In the wet season, little increase in conductivity level was observed in rainy months which might be attributed to the erosion of catchment soil from the Ziqlab wadi. Conductivity values did not show significant variation with depth (Fig.9, b), a condition that indicates a thermocline of very short duration. This indicates the homogeneity of the chemical composition of the reservoir water at both sampling sites. The reservoir conductivity values were higher than those reported by Saadoun *et al*., (2010) in Wad Al-Arab dam reservoir NW Jordan. In contrast with other lakes and reservoirs located in MENA region, conductivity values of Sharhabiel dam reservoir are rather high (Al-Tanni 2011, Coche 1974, Hall *et al*. 1977, Temperas *et al*. 2000).

Seasonal variations in organic matter content (COD and BOD_5) were also apparent, with peaks generally occurring in spring through early fall months (Fig.10, a).

The relative high concentrations of COD and BOD_5 were corresponded with high algal growth. A possible explanation for the seasonally low levels of COD in winter is due to reduced phytoplankton activity in response to low temperature and sunlight intensity (Fig.10, b). Furthermore, the high correlation coefficient between COD and BOD_5 (r=0.94) suggests that both are associated with similar sources and may probably be related to agricultural runoff, improper waste disposal, and wastewater effluent discharged into the reservoir.

ACKNOWLEDGMENTS

The author gratefully acknowledges use of the services and facilities at Yarmouk University, Jordan and data provided by Jordan Valley Authority. Appreciation is extended to the staff of Sharhabiel Dam reservoir for their great help and support.

REFERENCES

1. Abu-Rukah, Y., & Ghrefat, H., Ion chemistry of waters impounded by the Sharhabiel dam, Jordan, and weathering processes. *International Journal of Environmental Pollution.* **21**(3), 263-276 (2004).
2. Agrar & Hydrotecnik, National Water Resources Master Plan of Jordan. 8 Volumes, Essen, Hannover (1997).
3. Al-Ansari N., & Shanti A., Siltation of three small reservoirs in Jordan, *Al-Manara,* **12** (2):10-26 (2006).
4. Al-Handal A.Y., & Saadoun I., Phytoplankton composition and physical-chemical features of a hypertrophic reservoir in North Jordan: King Talal Reservoir, *River Idrobiology,* **40**; 305-320 (2001).
5. Al-Taani, A., Seasonal variations in water quality of Al-Wehda Dam north of Jordan and water suitability for irrigation in summer. *Arabian Journal of Geosciences,* doi:10.696 1007/s12517-011-0428-y (2011).
6. American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment federation (WEF). Standard methods for the examination of water and wastewater (20th ed.). Washington DC: APHA (1998)
7. Basnyat P, Teeter L, Lockaby BG, Flynn KM, Land use characteristics and water quality: a methodology for valuing of forested buffers. *Environ Manage* **26**: 153–161 (2000).
8. Batayneh, A., Al-Momani, I., Jaradat, R., Awawdeh, M., Rawashdeh, A., & Ta'any, R. Weathering processes effects on the chemistry of the main springs of the Yarmouk Basin, north Jordan. *Environmental Hydrology*, **16**; 20 (2008).
9. Bender, F., Geology of Jordan, Borntraeger, Berlin (1974).
10. Boyd C.E., Water chemistry and plankton in unfertilized ponds in pastures and in woods, *Trans Am. Fisher. Soc.,* **105**: 634-436 (1976).
11. Boyd C.E., Water quality in ponds for aquaculture, Birmingham Publ. Co., *Birmingham, Al.* pp 482.
12. Branco, C. W. C., Rocha, M. I. A., Pinto, G. F. S., Gomara, G.A., &Filippo, R. Limnological features of Funil Reservoir (RJ, Brazil) and indicator properties of rotifers and cladocerans of the zooplankton community. Lakes & Reservoirs: *Research and Management,* **7**; 87–92 (2002).
13. Carlson RE, A trophic state index for lakes. *Limnol Oceanogr* **22**(2): 361–369 (1977).
14. Cheng XY, Li SJ, An analysis of the evolvement processes of lake eutrophication and their characteristics of the typical lakes in the middle and lower reaches of Yangtze River. *Chin Sci Bull* **51**(13): 1603–1613 (2006).
15. Cloot, A., & Ros, J. C. Modeling a relationship between phosphorus, pH, calcium and chlorophyll-a concentration, *Water SA,* **22**; 49-55 (1996).
16. Coche A.G., Limnological study of a tropical reservoir. [In:] Man Made Lakes: The Accra Symposium, Eds., Obeng, L.E., pp. 116-122 (1974).
17. Dillon, P. J., & Rigler, F. H. The phosphorus—chlorophyll relationship in lakes. *Limnology and Oceanography*, **19**; 767–773(1974).
18. Dodds, W. K. Misuse of inorganic N and soluble reactive P concentrations to indicate nutrient status of surface waters. *Journal of the North American Benthological Society,* **22**; 743 171–181 (2003).
19. Dodds, W. K. Nutrients and the"dead zone": the link between nutrient ratios and dissolved oxygen in the northern Gulf of Mexico. *Frontiers in Ecology and the Environment,* **4**; 211–217 (2006).
20. Dokulil MT, Herzig A, An analysis of long-term winter data on phytoplankton and zooplankton in Neusiedler See, a shallow temperate lake, *Austria. AquatEcol* **43**:715–725DOI10.1007/s10452-009-9282-3 (2009).

21. Duyzer, J. H., Verhagen, H. L. M. & Erisman, J. W. The deposition of acidifying substances at the Asselsche Heide(in Dutch), MT-TNO Rep. R 89/029, Delft, The Netherlands (1989).
22. El-Radaideh, N., Al-Taani, A. A., Al-Momani, T., Tarawneh, K., Batayneh A., and Taani, A., Evaluating the potential of sediments in Ziqlab Reservoir (northwest Jordan) for soil replacement and amendment. *Lake and Reservoir Management,* **30**; 32-45 (2014). http://dx.doi.org/10.1080/10402381.2013.870263
23. Fandi, K. G., Qudsieh, I.Y., Muyibi, S. A., Massadeh, M. ”Water Pollution Status Assessment of King Talal Dam, Jordan.” *Adv. Environ. Biol.* **3**(1): 92-100 (2009).
24. Ferrier, R. C., Edwards, A. C., Hirst, D., Littlewood, I. G., Watts, C. D., & Morris, R. Water quality of Scottish rivers: spatial and temporal trends. *Science of the Total Environment,* **265**; 327–342 (2001).
25. Fonseca, R. M., Barriga, F. J., and Conceição, P. I., Clay minerals in sediments of Portuguese reservoirs and their significance as weathering products from over-eroded soils: A comparative study of the Maranhão, Monte Novo and Divor Reservoirs (South Portugal). *International Journal of Earth Science,* **99**; 1899-1916 (2010). http://dx.doi.org/10.1007/s00531-009-0488
26. Fonseca, R., Barriga, F. J. A. S., & Fyfe, W. S. Suitability for agricultural use of sediments from the Maranhão Reservoir. In M. A. C. Fragoso & M. L. Beusichem (Eds.), Optimization of plant nutrition (pp. 665–671). Dordrecht: Kluwer Academic Publishers (1993).
27. Fonseca, R., Canario, T., Morais, M., and Barriga, F., Phosphorus sequestration in Fe-rich sediments from two Brazilian tropical reservoirs. *Applied Geochemistry,* **26**; 16-7 (2011). http://dx.doi.org/10.1016/j.apgeochem.2011.04.017
28. Forsberg, C., & Ryding, S. O. Eutrophication parameters and trophic state indices in 30 Swedish waste-receiving lakes, *Archiv fuer Hydrobiologie,* **89**; 189–207 (1980).
29. Gaudet, J. J., & Muthuri, F. M. Nutrient relationships in shallow water in an African Lake. Lake Naivasha. *Oecologia,* **49**; 109–118 (1981).
30. Guildford, S. J., Hendzed, L. L., Kling, H. J., Fee, E. J., Robinson G. G. C., Hecky, R. E., *et al*. Effects of lake size on phytoplankton nutrient status. *Canadian Journal of Fisheries and Aquatic Sciences,* **51**; 2769–2786 (1994).
31. Hall A., Valente I.M., Davies B.H. The Zambezi Reiver in Mozambique: the physico-chemical status of the middle and lower Zambezi prior to closure of the Cabora Bassa Dam, *Freshwater. Biol.,* **7**: 187-206 (1977).
32. Hirsch, R.M., P.A. Hamilton, T .L. Miller. “U.S. Geological Survey perspective on water-quality monitoring and assessment.” *Journal of Environmental Monitoring* **8**: 512-518 (2006).
33. HKJ, Hashemite Kingdom of Jordan and GTZ (2008a). Water Resources in Jordan. National Master Water Plan
34. Jordan Valley Authority (1965) Completion Report of Ziqlab Dam, JVA, Govt. of Jordan,
35. Kelly, S. Report on the Green and Watch Lakes sewage contaminated seepage detection study (p. 23). Kamloops, British Columbia: Environmental Protection Division, Ministry of Environment (2009).
36. Kotut K., Krienitz L., Muthari M., Temporal changes in phytoplankton structure and composition at the Turkwel Gorge Reservoir, Kenya. *Hydrobiologia,* **368**: 41-59 (1998).
37. Levine, S. N., & Schindler, D. W. Influence of nitrogen to phosphorus supply ratios and physicochemical conditions on Cyanobacteria and phytoplankton species composition I the Experimental Lake Area, Canada. *Canadian Journal of Fisheries and Aquatic Sciences,* **56**; 451–466 (1999).
38. Macdonald, M., East Bank of Jordan Water Resources, Report 4, Storage on the Wadi Ziqlab, Jordan (1965a).
39. Macdonald, M., Wadi Ziqlab Dam, Geological Report on the Upper Dam Site, Jordan (1965b).
40. Madison, K. R. Diagnostic Feasibility Study Lake Kampeska(p. 107). Codington County, South Dakota: South Dakota Department of Environment and Natural Resources (1994).
41. Matthess, G. The properties of groundwater

(pp. 215–255). New York: John Wiley and Sons (1982).

42. Meybeck, M. Global chemical weathering of surficial rocks estimated from river dissolved loads. *American Journal of Science,* **287**; 401–428. Press, San Diego, CA (1987).
43. MWI, Ministry for Water and Irrigation, Water for Life - Jordan's Water Strategy 2008-2022 (2009).
44. Pridmore, R. D., Vant, W. N., & Rutherford, J. C. Chlorophyll–nutrient relationships in North Island lakes (New Zealand). *Hydrobiologia,* **123**; 181–189 (1985).
45. Rhee G.I., Effects of environmental factors and their interactions on phytoplankton growth, *Advances in Microbial Ecology,* **6**: 33-74 (1982).
46. Richardson CJ, King RS, Qian SS, Vaithiyanathan P, Qualls RG, Stow CA, Estimating ecological thresholds for phosphorus in the Everglades. *Environ Sci Technol* **41**(23):8084–8091 (2007).
47. Saadoun I, Batayneh E, Alhandal A, Hindiyeh M. Physicochemical features of Wadi Al-Arab Dam (reservoir), Jordan, *International Journal of Oceanography and Hydrobiology,* Vol. XXXIX, No.4, pp. 189-203 (2010). DOI 10.2478/v10009-010-0057-x.
48. Saadoun, I., Bataineh, E., Al-Handal, A. Y. The primary production condition of Wadi Al-Arab Dam (Reservoir), Jordan. *JJBS,* **1**; 67-62 (2008).
49. Shatnawi, A., Hydrological and Hydro chemical Study for Ziglab Dam, MSc. Thesis, Al al-Bayt University, Jordan (2002).
50. Soares, M. C. S., Marinho, M. M., Huszar, V. L. M., Branco, C. W. C., & Azevedo, S. M. F. O. The effects of water retention time and watershed features on the limnology of two tropical reservoirs in Brazil. Lakes & Reservoirs: *Research and Management,* **13**; 257–269 (2008).
51. Temponeras M., Kristiansen J., Moustaka-Gouni M., Seasonal variation in phytoplankton composition and physical-chemical features of the shallow lake Dorani, Macedonia, Greece, *Hydrobiologia,* **424**: 109-122 (2000)
52. Voros L and Padisak J. Phytoplankton biomass and chlorophyll-a in some shallow lakes in central Europe. *Hydrobiologia* **215**: 111-119 GMENTS (1991)
53. Water Authority of Jordan (WAJ), The North Jordan Water Resources Investigation Project, Amman, Jordan (1989)
54. Wetzel, R. In: Limnology; Lake and River Ecosystems, Third Edition. Academic (2001)
55. Wetzel, R. G. Limnology. Orlando, Florida: Saunders College Publishing (1983)
56. Yang X, Wu X, Hao H, He Z, Mechanisms and assessment of water eutrophication. *Journal of Zhejiang University of Science* **9**(3):197–209 (2008).
57. Zhao, P., Tang, X., Tang, J., & Wang, C. Assessing water quality of Three Gorges Reservoir, China, over a five-year period from 2006 to 2011. *Water Resources Management,* **27**; 4545–4558 (2013).