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Nutrients in Water and Sediments of King Talal Dam-Jordan.

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Abstract **الملخص**

Samples of water and sediments were collected from three sites along the main body of King Talal Dam (KTD) in the period between Spring 2007 and Winter 2008. The sites represent the middle point of KTD (site A), its deepest area (site B) and its outlet or intake point (site C). Samples were collected from surface and near-bottom water during four seasons within the study period, while the sediment samples were collected during dry (summer) and wet (winter) seasons within the same study period. In addition to temperature, dissolved oxygen (DO) and pH, water samples were analyzed for nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_3), dissolved inorganic phosphate-phosphorus; DIP (PO_4^-), total nitrogen (TN), and total phosphorus (TP) contents. Sediments samples were analyzed for grain size distribution, organic matter, total phosphorus (TP), and total nitrogen (TN). Nutrients in water fluctuated in space, depth and time. Nitrogen species concentrations were highest during spring, while higher phosphorus species concentrations were recorded during winter. However, nutrients showed significant differences between seasons and insignificant differences between sites and between depths. The concentrations of nutrients in the water were generally less than their concentrations in the sediments. Nutrients in sediments showed more or less similar general trend of spatial distribution, where maximum values occurred in site A and site B during winter, and most of the pollutants decreased towards the far end of the dam at its outlet or intake point (site C). The concentrations of nutrients were higher in the clay–silt size fraction (<63μm), which has higher organic matter contents compared to the larger size fractions. The results of the present study agree with and confirm the results of many previous studies which indicated that water and sediments of KTD are polluted due to many anthropogenic and natural sources. The results and its relationships with these sources are discussed in details.

Keywords: Nutrients, Water, Sediments King Talal Dam, Jordan.

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1. Introduction

As with most arid and semi-arid countries Jordan suffers from water shortages in domestic, agricultural and industrial demands. These shortages stem from the fact that the major supply is ground water, which is in turn dependent for its recharge, on the rates of rainfall, which vary from year to year (Stanley Consultants, 1978). The total area of Jordan is about 89,000 km², only 8.5% of this area receives more than 200 mm of annual rainfall (Rawajfih et al., 1988). The average annual rainfall ranges from 50 to 600 mm/year (Al-A′raj., 1997). The scarcity and uneven distribution of precipitation over Jordan results in limited surface and groundwater resources available for domestic, agricultural and industrial uses. Rapid population growth coupled with increased urbanization and industrialization have lead to the over-exploitation of aquifers and the contamination of diminishing supplies through inadequate industrial and municipal wastewater treatment capacities. Setting of industrial plants near or immediately upstream from potable supplies; and overuse and misuse of pesticides, insecticides, fungicides and fertilizers are among the factors that have lead to pollution of the limited ground and surface water resources (Al-Jayyousi and Shatanawi, 1995).

Realizing all these conditions, Jordan has built many dams of various storage capacities in order to store it for different purposes such as domestic, agriculture and industry uses and to control floods, improve drainage, collect water from rivers and streams. Among these artificial surface water bodies is King Talal Dam (KTD); it is an earth-fill dam that was constructed in the period 1972-1978. The total storage capacity of the dam is 85 million cubic meters (MCM). The main lake behind the dam is 7.50 kilometers long and 450 meters wide (area 33.75 km^2) (RSS reports, 1984-2005, Numayr, 1999). The dam which was constructed within the main course of Zarqa River at a discharge of 40 kilometers northwest of Amman, receives its major inflow as natural run-off from Zarqa River and major springs. The Zarqa River is the third largest river in the region in terms of its annual discharge and its waters are extensively used for irrigation and industrial needs. The area of the Zarqa River catchment is about 3468 Km² (RSS, 1981). Other inflow comes from small springs, and effluents from Al-Samra, Jerash and Baqa'a sewage treatment plants, and from industrial plants between Amman and Zarqa. The plants effluents contribute about 50% of the water reaching the dam where the average annual inflow is about 113 MCM (Bandel and Salameh, 1979, 1981; Salameh, 1991; RSS, 1984-2004; Numayr, 1999).

Wadi Rmemeen drainage which is composed basically from the wastewater from AlBaqa'a treatments plant in addition to some water springs that are spread all over the valley represents the second important source of water discharged into the dam (RSS, 2005). Khirbet Assamra effluent and the industrial wastewater discharged into the dam via Zarqa River has relatively high concentration of heavy metals, phosphorus and ammonia which have adversely affected the quality of water in King Talal Dam (Salameh, 1980; Sigg et al., 1987; Britton, 1999; Alawneh, 1997; Mahasneh and Soub, 1983; Hashwa, 1985; Al-Soub, 1981; Al-Jassabi and Khalil, 2006; RSS, 2005), and consequently limited the use of its water for irrigation purposes (Saqqar, 1994). It has been reported that the dam is suffering from sedimentation problems and the sediments entering the dam contain nutrients and heavy metals, and from the cyanobacteria *Microcystis aeruginosa* which forms extensive summer blooms in its water (Numayer, 1999).

Phosphorus (P) and nitrogen (N) are essential nutrients necessary for the growth of plants in water bodies. Of these two nutrients, phosphorus is most often considered to be the nutrients that regulate the production of algae in water bodies and is most amenable to control (Schindler, 1977).

Anthropogenic activities, including fertilizer application, in combination with channelization of streams in the agricultural areas, have lead to increased N and P loads carried by streams, with their concentrations in water bodies often exceeding drinking water standards (David et al., 1997) and thus contributed to a number of human health problems (Townsend et al., 2003), eutrophication of surface waters (Carpenter et al., 1998), and seasonal hypoxia in many regions (Goolsby et al., 2001). This undesirable process can lead to deterioration of water quality and significant economic repercussions (Cooke and Kennedy, 2001).

The growth and development of phytoplankton communities and consequently water bodies productivity depend on the recycling of nutrients already incorporated in living organisms, or the supply of new nutrients (Reynolds, 1997). In addition, nutrients may be adsorbed to the sediments accumulated on the bottom of rivers or lakes and other water bodies. These sediments can act as new nutrient sources to the overlying water (Masunaga et al., 1993; Abrams and Jarrell, 1995).

Many studies have been carried out on KTD environment during the past two and half decades. Most of these studies have focused on measuring the level of various pollutants in KTD water and sediments. However, little attention was devoted to the distribution and relationship of nutrients with other environmental parameters in water and sediments of the dam. Therefore, this study was initiated to fill a gap in the information on this relationship, to examine the factors affecting the environmental conditions of the dam, and to provide useful and usable information about nutrients and other pollution indicators in the dam environment.

2. Materials and Methods:

2.1. Sampling Sites:

Samples of water and sediments were collected from three sites along the main body of King Talal Dam (Fig. 1): Site (A) which is located at latitude N 32º 19' 001" and longitude E 35º 80' 887" represents a middle point in King Talal Dam, Site (B) is located at latitude N 32º 19' 025" and longitude E 35º 80' 519" and represents the deepest area in the main body of King Talal Dam, and Site (C) at latitude N 32º 19 193' and longitude E 35º 80 343' and represents the outlet of King Talal Dam and the intake point that feeds King Abdullah Canal (RSS reports, 1984-2005).

2.2. Samples Collection, Transportation, Storage and Treatment:

Surface and near-bottom water samples were collected from the selected locations by the use of a 10 liter PVC Niskin water sampler on seasonal basis between April 2007 and April 2008. Sub-samples were taken from the sampler and put in a prelabeled, precleaned acid washed polyethylene bottles. The bottles were also washed with water from the samples before they were filled with sampled water. The bottles were kept in an ice box and covered with crushed ice until they were transported to the laboratory. Dissolved oxygen samples were transferred into clean dissolved oxygen bottles and treated properly with 2 ml of manganese sulfate solution $MnSO_4.H_2O$ and 2 ml of alkaline iodide reagent (NaOH+NaI) were added below the surface of the water samples.

In the laboratory, water samples were treated, preserved and stored as recommended by and described in the APHA (1998). Sediments samples were collected from the same sampling points of water by the use of a stainless steal grab sampler. Collected samples were put in acid-washed polyethylene bags and kept in an ice box that contain crushed ice until they were transported to the laboratory. In the laboratory, parts of the sediments samples were wet sieved on a 63 µm sieve. Sediment samples were then dried in an oven at 105 C^o. After drying, samples were homogenized by the use of agate pestle and mortar before being split into sub-samples for future use and analysis**.**

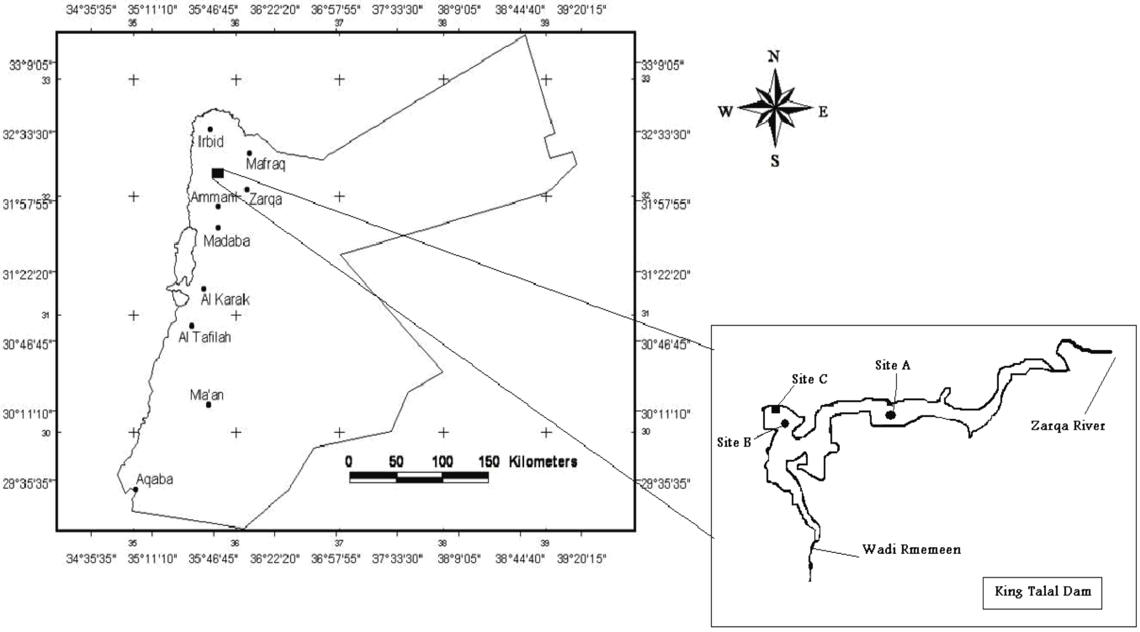

Figure 1: Locations of sampling sites in the main body of King Talal Dam.

2.3. Water Analysis:

Temperature of water was measured *in situ* by the use of a portable thermometer. The pH of water was determined by the use of a pH meter equipped with a standard hydrogen electrode and a reference electrode. Transparency was measured by the use of a 30 cm diameter Secchi disc, which was lowered on the shaded side of the boat. The average depth of two measurements was recorded as the disc transparency. Dissolved oxygen (DO) was determined by the use of the Winkler method as described in the APHA (1998). All nutrients were determined as described in the APHA (1998). Nitrite (NO_2^-) was determined by the diazotisation of sulphanilamide solution by nitrates in the sample to form diazo compound. The compound couples with N-(1-naphthyl)-ethylene diamine solution to form a purplish-pink dye. Nitrate (NO_3^-) was determined by the use of the ultraviolet spectrophotometric screening method. Ammonia (NH_3) was determined by the use of the Nesslerization method. Phosphate (PO_4^-) was determined by the use of the ammonium molybdate-ascorbic acid method. Total phosphorus (TP) and total nitrogen (TN) in water samples were determined as dissolved (reactive) phosphate and as nitrate (APHA, 1998) after digestion with alkaline potassium persulphate solution.

a) Oxidizing Reagent:

50 g of potassium persulphate and 30 g boric acid were dissolved in 250 ml of 1 M sodium hydroxide solution. Then solution was made up to 1000 ml with deionized water and stored in a brown bottle at room temperature, protected from direct light.

b) Digestion and Analysis Procedures:

4 ml of the oxidizing reagent were added to 30 ml of sample in 50 ml autoclaved bottles. Samples were boiled in a stainless steel pressure cooker for 20 minutes.

The bottles were allowed to cool. The volume of the digest was adjusted to 40 ml with distilled water. For the determination of total nitrogen as nitrate, 1 ml of the 2.5 % buffer solution (ammonium chloride) were added to 10 ml of digested sample and the volume were adjusted to 50 ml with distilled water. The procedure was continued as described in the APHA (1998). Aliquots of 25 ml of the digested samples were used to determine the concentration of total phosphorus as dissolved inorganic phosphorus by the use of the ammonium molybdate-ascorbic acid method as described in the APHA (1998).

2.4. Sediments Analysis:

The analysis of sediments was performed on the bulk sediments, fractions larger than 0.063 mm (>63 µm) and less than 0.063mm (mud). These fractions were analyzed for organic matter, total phosphorus, total inorganic phosphorus and total nitrogen. Organic matter was determined according to the method of Walkley and Black (1934) as described in the APHA (1998). Total phosphorus (TP) was determined by use of the perchloric acid method as described in the APHA (1998). Total inorganic phosphorus (TIP) was determined according to (Andersen, 1976): 1 g of sediments was ignited in a muffle furnace at a temperature of 550 C^o for 1 hour, dissolved in 25 ml of 1 M HCl solution and determined as total inorganic phosphorus according to Strickland and Parsons (1972). Total Nitrogen was determined as ammonia: 1 g of each sediment sample was treated with 2 ml of sulphuric acid. The sample was heated on a hotplate for 2-3 hours. Aliquots of 50 ml of deionized water were added to each sample. The sample was filtrated through No. 41 Whatman filter paper. The filtrate of each sample was made up to 250 ml with deionized water and 55 ml of 1 M sodium hydroxide solution. An aliquot of the digest was used for the determination of total nitrogen as ammonia using the spectrophotometric method as described in APHA (1998).

2.5. Statistical analysis:

Results are presented as means ± standard deviation (S.D.) and the one way ANOVA and multiple comparison tests were used to evaluate differences between means (confidence interval=95%). Also results were analysed by analysis of correlations and relationships between different factors.

3. Results and Discussion:

3.1. Water/ Spatial and Temporal Effects:

3.1.1. pH, Temperature and Dissolved Oxygen:

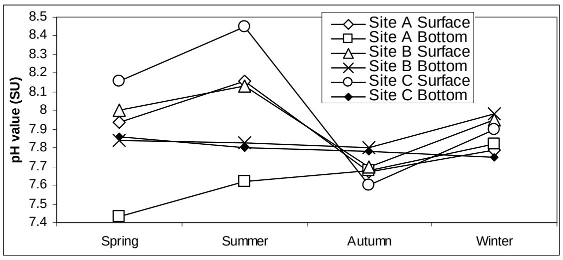

Figure 2: Mean value of pH (SU) in KTD surface and near-bottom water during the four seasons.

The examination of the results in figure 2 indicate that the pH of the surface water ranged between 7.60 and 8.45 with an overall mean value of 7.96 while pH of the near-bottom water ranged between 7.40 and 7.98 with an overall mean value of 7.77. The highest value was recorded in the surface water of the Intake Area of the Dam (site C), while the lowest values were recorded in the near-bottom water of the Mid Point of the Dam (site A). Seasonally, the distribution of pH in the four seasons was in the following order: summer > spring > winter > autumn (Fig. 2). The one way ANOVA test (Table 3) showed significant differences between sites, between depths and between seasons.

The higher values of pH in the surface water compared to those of the near-bottom water can be attributed at least partially to the CO_2 consumption by photosynthetic activity of algae and other flora in the surface water and in the euphotic zone. In addition, Zarqa River and Wadi Rmemeen receives combined industrial and waste water discharges of alkaline nature. According to Hellawell (1986) discharges of alkaline nature may increase the pH values of the surface waters above 8 to 9 or 10. The lower pH values in the near-bottom water can be attributed to lower levels of DO in the near-bottom water compared to the surface water, due to decomposition and higher levels of OM, and lower rate of photosynthetic activity in this water. Higher pH values were recorded during summer and spring, which represent the periods of low water flow, and the increased percentage of the alkaline industrial wastewater in the total flow into the reservoir. High summer pH could also be caused by CO_2 removal via algal photosynthesis which may counter balance the effect of increasing water temperature.

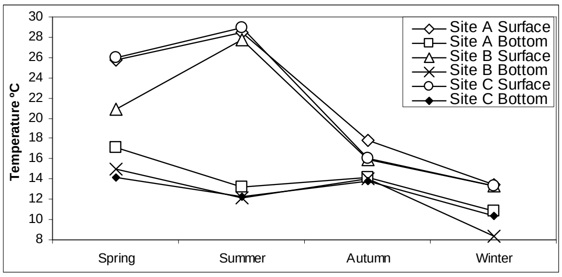

Figure 3: Mean value of temperature in KTD surface and near-bottom water during the four seasons.

Mean temperature of the surface water samples ranged between 13.30 and 28.90 ˚C with an overall mean value of 20.70 ˚C while, the mean temperature of the near-bottom water ranged between 8.30 and 17.10 ˚C with an overall mean value of 12.90 ˚C. The highest value was recorded in the surface water of site (A) followed by site (C). The lowest value was recorded in the near-bottom water of site (B). The seasonal distribution of temperature was in the following order: summer > spring > autumn > winter (Fig. 3). The one way ANOVA test (Table 3) showed significant differences between depths and between seasons and in significant differences between sites.

It is known that water temperature depends on many factors that include climate, altitude, air temperature, seasons of the year, the ratio of the water's surface area compared to its depth, input of discharge, and water flow rate (Best, 1975; USEPA, 1976). The high surface temperature is attributed to the direct contact with sun light. Temperature value fluctuated seasonally and has a general seasonal trend similar to that of air temperature. As expected, the lowest temperature was recorded during winter, while the high temperature was recorded in summer due to the effect of solar heating on the surface water of KTD.

In summer, sunlight heats the surface layer of the water (temperature of surface layer begins to rise) but the temperature in deep layer remains low compared to the surface layer. Such thermal stratification results in low dissolved oxygen (DO) concentrations in the hypolimnion during the summer time. This stratification is considered an essential element for very high density blooms of algal growth in King Talal Dam (KTD). When these algae and other phytoplankton and zooplankton settle into the deeper water where they are decomposed, decomposition takes up oxygen and gives off carbon dioxide and produces the anaerobic products such as H_2S and NH_4. It has been reported that KTD as a warm monomictic waterbody, experiences overturn between surface and bottom waters once a year during autumn (RSS, 2005; Numayr, 1999).

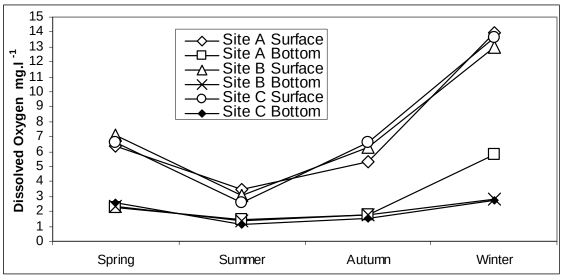

Figure 4: Mean concentration of DO in KTD surface and near-bottom water during the four seasons.

The results (Fig. 4) show that the DO in the surface water varied widely in the range of 2.60 -13.90 mg/l, with an overall mean value of 7.30 mg/l while the mean concentration of DO in the near-bottom water varied in the range of 1.10-5.80 mg/l with a much lower overall mean value (2.3 mg/l) as compared to the surface water. The highest mean concentration of DO was recorded in the surface water of site (A) while the lower mean values were recorded in the near-bottom water of sites (C) and (B). The seasonal distribution of DO concentration was in the order: winter > spring > autumn > summer. The one way ANOVA test (Table 3) showed significant difference in DO between depths and between seasons and insignificant difference between sites. High values of DO in surface water are not unusual and are mainly attributed to the direct contact of surface water with air and to the relatively higher photosynthetic activity compared to that in the near-bottom water. In contrast, lower DO values in the deeper water are attributed to the degradation of organic substances that are accumulated in the deeper water (USEPA, 1976). The high DO values in winter is attributable to relatively low temperature of water (higher solubility of gases) and high input of flood water that contains high oxygen levels due to the possibility of mixing with atmospheric oxygen. Low values of DO during summer can be attributed to the relatively high water temperature, higher oxidation rate of NH_4 (nitrification), and other biodegradable organic material which consumes oxygen during its oxidation.

3.2. Nitrate, Ammonia, Nitrite and Total Nitrogen:

Nitrate (NO_3^-), ammonia (NH_3), nitrite (NO_2^-) and total nitrogen (TN) concentrations in the water of the three sampling sites (A, B, C) within the main body of King Talal Dam are presented in Table (2) and represented in Figures (5), (6), (7) and (8).

The results (Fig. 5) indicate that nitrate concentration in the surface water ranged between 0.002 and 38.60 mg/l with overall mean value of 16.20 mg/l, while the concentration in the near-bottom water ranged between 0.15 and 36.3 mg/l with overall mean value of 15.7 mg/l. Relatively higher mean concentrations of nitrate in surface and near-bottom water were recorded in site (A) and site (C) compared to site (B).

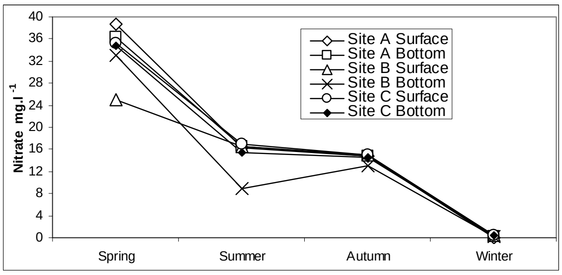

Figure 5: Mean concentration of nitrate in KTD surface and near-bottom water during the four seasons.

Seasonally, the levels of nitrate concentration were in the order: spring > summer > autumn > winter. The one way ANOVA test (Table 3) showed significant differences between nitrate concentration in different seasons and insignificant differences between sites and between depths.

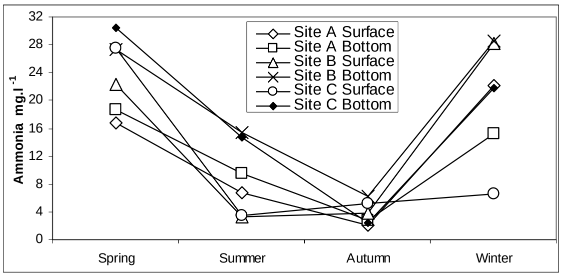

Figure 6: Mean concentration of ammonia in KTD surface and near-bottom water during the four seasons.

The results of ammonia (Fig. 6) indicate that the mean concentrations in the surface water ranged between 2.12 and 28.20 mg/l, with overall mean value of 12.33 mg/l while, ammonia in the near-bottom water ranged between 2.51 and 30.50 mg/l, with overall mean value of 16.10 mg/l, the highest mean concentrations were recorded in the near-bottom and surface water of site (B) followed by site (C). Seasonally, the levels of ammonia concentration were in the order: spring > winter > summer > autumn. Similar to nitrate, the one way ANOVA test (Table 3) showed significant differences in ammonia concentrations between seasons and insignificant differences between sites and between depths.

Figures 5 and 6 show that the concentrations of nitrate were generally higher in the surface water, while ammonia concentrations were generally high in deeper water. This distribution can be attributed to the more oxic conditions in the surface water which enhances the nitrification process compared to less oxic or anoxic conditions in the deeper near-bottom water that enhances the production of ammonia (denitrification) in this type of water (Van Den Bos, 2003).

Figure 6 shows also that the concentration of ammonia was generally low in the dry seasons (summer and autumn) because biota are more efficient in utilising ammonia under dry conditions and because dry weather, sunshine and higher water temperature enhances the process of oxidation and nitrification of ammonia (Seager et al., 1988). In contrast, during rainy or wet seasons the temperature of water is low, biological growth is minimal and nitrification process is slow which give rise to high concentration of ammonia (Seager et al., 1988).

The results as presented in Figure 7 show that the mean concentration of nitrite in the surface water ranged between 0.09 and 2.23 mg/l with overall mean value of 1.44 mg/l, while its mean concentration in the near-bottom water ranged between 0.10 and 3.14 mg/l, with overall mean value of 1.46 mg/l. Similar to nitrate, higher mean concentrations of nitrite were recorded in the near-bottom water of site (A) and site (C) compared to site (B). Seasonally, the levels of nitrite concentration were in the order: autumn > spring > summer > winter. Similar to the case of nitrate and ammonia, the one way ANOVA test (Table 3) showed significant differences in nitrite concentrations between different seasons and insignificant differences between sites and between depths.

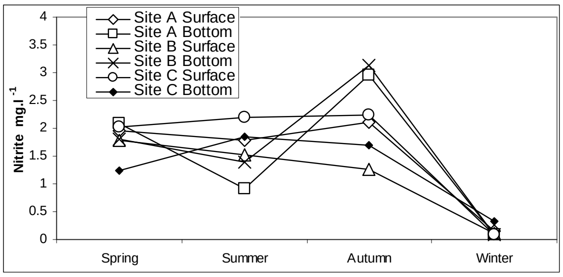

Figure 7: Mean concentration of nitrite in KTD surface and near-bottom water during the four seasons.

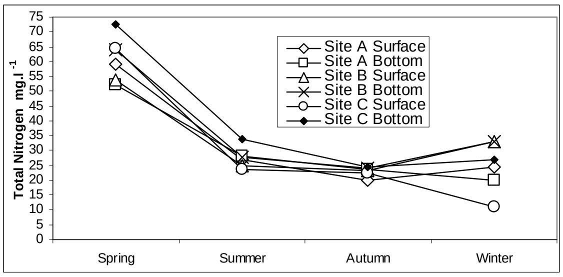

Figure 8: Mean concentration of total nitrogen in KTD surface and near-bottom water during the four seasons.

The results (Fig. 8) indicate that mean total nitrogen concentration (TN) in the surface water samples ranged between 11.18 and 64.40 mg/l with overall mean value of 32.30 mg/l, while its mean concentration in the near-bottom water ranged between 20.10 and 72.60 mg/l with overall mean value of 35.90 mg/l. The high mean concentrations were recorded in sites B and C compared to site A. Seasonally, the levels of total nitrogen were in the order: spring > summer > winter > autumn. The one way ANOVA test (Table 3) showed significant differences in total nitrogen concentrations between different seasons and insignificant differences between sites and between depths. The concentration of inorganic nitrogen which includes ammonia, nitrite and nitrate is usually affected by many factors that include water temperature and pH, in addition to surface runoff from the surrounding catchment area, streams, discharge of effluent from wastewater treatment plants, agricultural fertilizers and industrial wastes which are considered major sources of inorganic nitrogen entering aquatic systems (Anon, 1996). Ammonia (NH_3) and ammonium (NH_4^+) are the reduced forms of inorganic nitrogen and their relative proportions are controlled by water temperature and pH. This explains the low levels of ammonia in the surface water during summer which is characterized by higher temperature, pH and dissolved oxygen as compared with the near-bottom water and with winter time. Nitrite (NO_2^-) is the intermediate inorganic species of the interconversion of nitrate and ammonia. In the aquatic ecosystem, nitrite is converted to nitrate rapidly under oxidizing conditions. Therefore, nitrate is usually far more abundant in the aquatic environment (Anon, 1996). This explains the relatively high concentrations of nitrate (Fig. 8) compared to nitrite concentration (Fig. 7) during the whole study period.

The relatively high concentrations of nitrate, ammonia and TN in KTD during spring has been attributed to the high amount of the nutrients that enter KTD during this season from Zarqa River and Wadi Rmemeen effluents (RSS, 2005), and to the wastewater that comes from As-Samra and Al Baqa´a treatment plants (Numayr, 1999).

3.3. Phosphorus and Total Phosphorus:

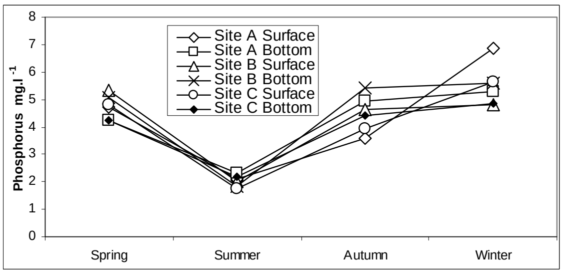

Figure 9: Mean concentration of phosphorus in KTD surface and near-bottom water during the four seasons.

The results (Fig. 9) indicate that the dissolved inorganic phosphorus in the surface water ranged between 1.80 and 6.90 mg/l with overall mean value of 4.19 mg/l, while its mean concentration in the near-bottom water ranged between 1.80 and 5.60 mg/l, with overall mean value of 4.21 mg/l. Higher mean concentrations of phosphorus were recorded in sites B and A as compared with those recorded in site C. Seasonally, the levels of phosphorus concentration was in the following order: winter > spring > autumn > summer. As in the case of the nitrogen species, the one way ANOVA test (Table 3) showed significant difference in phosphorus concentrations between seasons, and insignificant differences between sites and between depths.

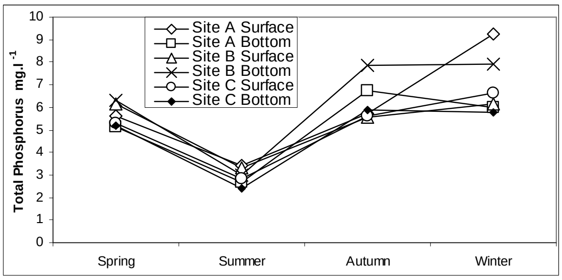

Figure 10: Mean concentration of total phosphorus in KTD surface and near-bottom water during the four seasons.

Figure 10 indicates that the total phosphorus in the surface water ranged between 2.90 and 9.20 mg/l, with overall mean value of 5.50 mg/l, while its mean concentration in the near-bottom water ranged between 2.40 and 7.60 mg/l, with overall mean value of 5.40 mg/l. Comparatively, high mean concentrations of total phosphorus were recorded in site A and site B, compared to those recorded in site C. Seasonally, the distribution of total phosphorus was in the following order: winter > autumn > spring > summer. Similar to dissolved inorganic phosphorus and all other nutrients the one way ANOVA test (Table 3) showed no significant difference in the concentration of total phosphorus between sites and between depths, and significant difference between seasons.

The high (TP) concentration at site A is in agreement with what has been reported by the RSS and has been attributed to the industrial wastewater as well as to the municipal wastewater reaching the dam from Khirbet As-Samra treatment plant (RSS, 2005). By comparison, the high phosphorus (PO_4-P) concentration at site B can be attributed to the agricultural activities and related fertilizers and to the wastewater from Al-Baqa´a sewage treatment plants that enters the dam via Wadi Rmemeen (RSS, 2005).

Seasonally, higher phosphorus and total phosphorus concentrations were recorded during winter while lowest concentrations were recorded during summer. Ekholm et al. (2000) suggests that the rainfall during winter is able to carry soil erosion products and agricultural waste such as chemicals fertilizers as well as wastewater from the treatment plants. Algal growth and phosphorus uptake by plankton and algae is triggered in spring and continue in a higher rate during summer. This uptake and growth process explains why the phosphorus concentration in the water is reduced to lower levels during summer. Later in the year plankton begins to dye off due to the lack of nutrients. The dead plankton containing the assimilated phosphorus falls through the water column and the degradation of plankton releases phosphorus back to the water column during autumn. This will result in an increase in the phosphorus concentration in water column during autumn. The process continues and phosphorus concentration increases and reaches maximum levels in winter when there is minimal photosynthesis activity by the plankton (Dojlido and Best, 1993; Harris, 1986; HMSO, 1980; Golachowska, 1979).

Table (1): Average concentrations of pH, temperature and dissolved oxygen in surface and near-bottom waters of King Talal Dam during spring, summer, autumn and winter.

Water	Site	Season		pH (SU)	Temp. (°C)	D.O (mg/l)
Surface Water	Mid Point of the Dam (A)	Spring	$\bar{X}$ ±S.D	7.95±0.07	25.80±0.60	6.35±0.20
		Summer	$\bar{X}$ ±S.D	8.16±0.01	28.50±0.40	3.50±0.40
		Autumn	$\bar{X}$ ±S.D	7.67±0.01	17.80±0.50	5.20±2
		Winter	$\bar{X}$ ±S.D	7.79±0.03	13.40±0.20	13.90±0.70
	Deepest Point of the Dam (B)	Spring	$\bar{X}$ ±S.D	8.04±0.03	20.90±5	7.10±0.50
		Summer	$\bar{X}$ ±S.D	8.13±0.01	27.83±0.30	3.10±0.40
		Autumn	$\bar{X}$ ±S.D	7.70±0.02	15.88±0.10	6.30±0.08
		Winter	$\bar{X}$ ±S.D	7.95±0.02	13.30±0.50	13±0.70
	Intake Point of the Dam (C)	Spring	$\bar{X}$ ±S.D	8.16±0.03	26±0.20	6.60±0.01
		Summer	$\bar{X}$ ±S.D	8.45±0.01	28.90±0.40	2.60±0.80
		Autumn	$\bar{X}$ ±S.D	7.58±0.10	16.10±0.30	6.60±0.09
		Winter	$\bar{X}$ ±S.D	7.88±0.01	14.30±0.20	13.60±0.40
Near-Bottom Water	Mid Point of the Dam (A)	Spring	$\bar{X}$ ±S.D	7.43±0.01	17.13±0.20	2.30±0.10
		Summer	$\bar{X}$ ±S.D	7.62±0.03	13.20±0.20	1.45±0.80
		Autumn	$\bar{X}$ ±S.D	7.68±0.02	14.10±0.10	1.80±0.20
		Winter	$\bar{X}$ ±S.D	7.82±0.01	10.80±0.40	5.78±1.90
	Deepest Point of the Dam (B)	Spring	$\bar{X}$ ±S.D	7.84±0.10	15.10±0.06	2.35±0.10
		Summer	$\bar{X}$ ±S.D	7.84±0.03	12.10±0.20	1.35±0.30
		Autumn	$\bar{X}$ ±S.D	7.80±0.010	14±0.20	1.77±0.30
		Winter	$\bar{X}$ ±S.D	7.98±0.05	8.33±0.30	2.83±0.20
	Intake Point of the Dam ©	Spring	$\bar{X}$ ±S.D	7.86±0.08	14.20±0.08	2.56±0.01
		Summer	$\bar{X}$ ±S.D	7.80±0.08	12.19±0.10	1.09±0.20
		Autumn	$\bar{X}$ ±S.D	7.78±0.07	13.80±0.30	1.52±0.01
		Winter	$\bar{X}$ ±S.D	7.75±0.03	10.40±0.50	2.76±0.07

$\bar{X}$: Mean. S.D: Standard Deviation.

Table (2): Average concentrations of nutrients (mg/l) in surface and near-bottom waters of King Talal Dam during spring, summer, autumn and winter.

Water	Site	Season		NO_3^-	NO_2^-	NH_3	TN	P	TP
Surface Water	**Mid Point of the Dam (A)**	Spring	$\bar{X}$ ±S.D	38.60±5.50	1.95±0.2	16.70±4.10	59.20±6.90	4.73±0.25	5.64±0.50
		Summer	$\bar{X}$ ±S.D	16.40±3.30	1.79±0.37	6.80±0.81	26.90±4.60	2.08±0.18	3.41±1.50
		Autumn	$\bar{X}$ ±S.D	14.70±2.40	2.12±0.28	2.12±0.33	20±2.30	3.60±0.30	5.70±1.90
		Winter	$\bar{X}$ ±S.D	0.002±1^{-1}	0.14±5^{-1}	22.10±5.30	24.50±2.60	6.88±0.29	9.23±1.65
	Deepest Point of the Dam (B)	Spring	$\bar{X}$ ±S.D	25±4	1.78±0.34	22.30±1.80	53.80±8.30	5.33±0.40	6.13±0.40
		Summer	$\bar{X}$ ±S.D	16.50±3.20	1.53±0.24	3.40±0.31	25±1.80	2±0.22	3.33±0.26
		Autumn	$\bar{X}$ ±S.D	15.10±4.10	1.27±0.16	3.80±0.30	23.30±2.40	4.66±0.21	5.56±0.38
		Winter	$\bar{X}$ ±S.D	0.33±0.02	0.11±0.01	28.20±6.50	32.90±5.80	4.83±0.32	6.17±0.42
	Intake Point of the Dam (C)	Spring	$\bar{X}$ ±S.D	35.12±6	2±0.29	27.50±4	64.40±9.50	4.81±0.37	5.32±0.45
		Summer	$\bar{X}$ ±S.D	17±5.70	2.19±0.3	3.42±1.10	23.60±2.70	1.77±0.14	2.86±0.37
		Autumn	$\bar{X}$ ±S.D	14.95±3.10	2.23±0.26	5.24±0.40	22.20±1.50	3.95±0.36	5.64±0.50
		Winter	$\bar{X}$ ±S.D	0.49±0.02	0.09±1^{-1}	6.45±1	11.20±1.40	5.63±0.40	6.61±0.82
Near-Bottom Water	**Mid Point of the Dam (A)**	Spring	$\bar{X}$ ±S.D	36.30±4.90	2.08±0.33	18.70±4.10	52±2	4.26±0.20	5.16±0.35
		Summer	$\bar{X}$ ±S.D	16.60±3.20	0.91±0.25	9.61±1.60	28.30±3.50	2.30±0.25	2.70±0.62
		Autumn	$\bar{X}$ ±S.D	14.80±3.30	2.95±0.3	2.83±0.25	23.70±2.30	4.94±0.34	6.73±1.70
		Winter	$\bar{X}$ ±S.D	0.19±5^{-3}	0.10±2^{-3}	15.30±3.30	20.10±1.70	5.30±0.24	6±1.60
	Deepest Point of the Dam (B)	Spring	$\bar{X}$ ±S.D	33.10±6.50	1.81±0.2	27.30±2.40	64.20±8.10	5.07±0.41	6.30±0.66
		Summer	$\bar{X}$ ±S.D	8.95±2.80	1.39±0.25	15.40±4.30	27.70±2.60	1.82±0.17	2.99±0.17
		Autumn	$\bar{X}$ ±S.D	13±2.40	3.14±0.4	6.21±0.37	24.10±3.30	5.40±0.12	7.87±0.67
		Winter	$\bar{X}$ ±S.D	0.15±0.01	0.09±1^{-1}	28.50±6.60	33±3.40	5.60±0.14	7.91±0.41
	Intake Point of the Dam (C)	Spring	$\bar{X}$ ±S.D	34.80±3.40	1.24±0.25	30.50±4.20	72.60±14.50	4.26±0.21	5.21±0.37
		Summer	$\bar{X}$ ±S.D	15.50±40	1.85±0.6	14.60±1.70	33.80±3.60	2.18±0.15	2.43±0.04
		Autumn	$\bar{X}$ ±S.D	14.60±3.30	1.69±0.1	2.51±0.15	24.30±3.10	4.43±0.35	5.88±0.30
		Winter	$\bar{X}$ ±S.D	0.46±0.02	0.32±0.45	21.80±3.20	27.10±2.50	4.84±0.33	5.78±0.60

$\bar{X}$: Mean. SE: S.D: Standard Deviation.

Table (3): P-Values of nutrients, pH, temperature and dissolved oxygen in KTD Waters. (confidence interval 95%)

	Between sites	Between depths	Between seasons
Nitrite	0.89 (N.S)	0.88 (N.S)	<0.0001 (S)
Ammonia	0.13 (N.S)	0.06 (N.S)	<0.0001 (S)
TN	0.67 (N.S)	0.31 (N.S)	<0.0001 (S)
Phosphorus	0.54 (N.S)	0.89 (N.S)	<0.0001 (S)
TP	0.33 (N.S)	0.55 (N.S)	<0.0001 (S)
Nitrate	0.57 (N.S)	0.86 (N.S)	<0.0001 (S)
pH	0.01 (S)	<0.0001 (S)	<0.0001 (S)
Temperature	0.55 (N.S)	<0.0001 (S)	<0.0001 (S)
DO	0.92 (N.S)	<0.0001 (S)	<0.0001 (S)

(S): Significant (N.S): Not Significant

3.4. Sediments/ Spatial and Temporal Effects:

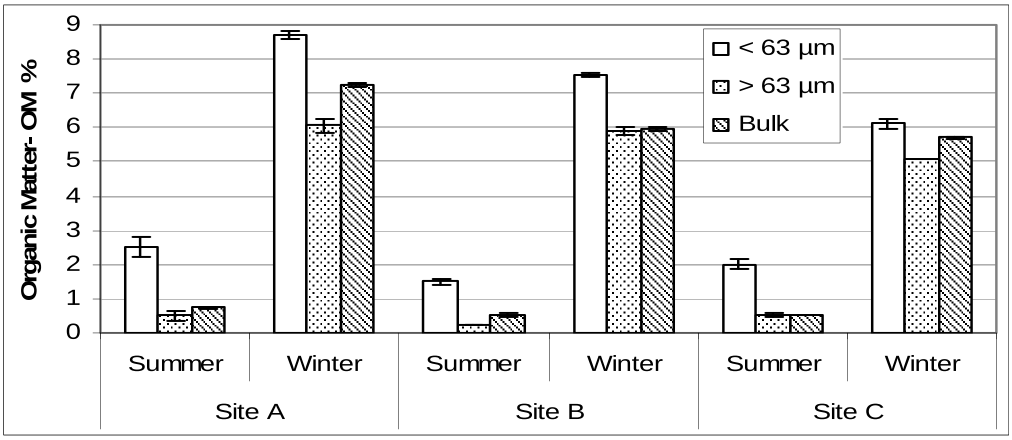

Figure 11: Mean percentage of OM ± SD in KTD sediments during dry (summer) and wet (winter) seasons.

Organic matter (OM) contents % in KTD sediments ranged between 0.25 and 8.7% with overall mean value of 3.70% (Table 4 and Figure 11). Highest overall mean values during winter and summer occurred at site A (mid point of the dam) followed by site B (deepest site of the dam) with mean values of 4.29 and 3.61 %, respectively. The lowest overall mean values were found at site C (intake point of the dam) with a value of 3.33 %. The less than 63 µm sediment fraction showed the highest OM contents which is in agreement with what has been widely reported, that OM contents of the sediments are predominantly associated with the fine fraction, through adsorption at clay surfaces (Greenland and Hays, 1981). Particulate matter from surface runoff, decay of plants especially in winter and municipal and industrial wastewater can be considered important sources for OM in the sediments of the dam. The one way ANOVA test (Table 5) showed significant difference in the OM between seasons and between fractions and insignificant difference between sites.

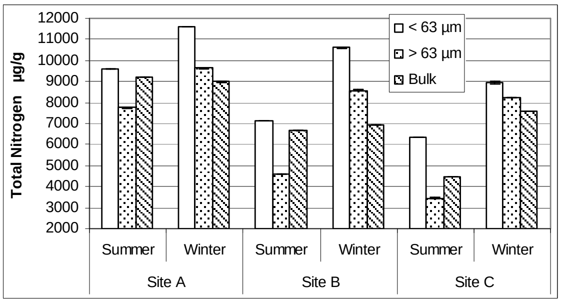

Figure 12: Mean concentration of TN ± SD in KTD sediments during dry (summer) and wet (winter) seasons.

The results (Fig. 12) show that the concentrations of total nitrogen (TN) in KTD sediments ranged between 3459 and 11604 µg/g (Table 4), with overall mean value of 7797 µg/g. Higher overall mean concentrations in winter and summer were recorded in site A followed by site B with concentrations of 9464 and 7422 µg/g, respectively. Relatively lower overall mean concentrations were recorded in site C (6506 µg/g). The highest concentrations at site A are attributed to the effluents of As-Samra wastewater treatments plants as well as to the runoffs from the agricultural land around the dam. The results as presented in the figure show clearly that the less than 63 µm sediment fraction has the highest contents of TN. Higher values were recorded in winter, which can be attributed to the fact that during this season the dam receives wastewater effluents and runoffs from agricultural land that contains high concentration of nutrients. The ANOVA test (Table 5) showed the presence of significant differences in TN contents between sites, between sediment fractions and between seasons. Table (4) and Figures (13a and 13b) show the concentration of total phosphorus (TP) and inorganic phosphorus (IP) in the sediments of King Talal Dam (sites A, B and C). The concentrations of TP (Fig. 13a) ranged between 1857 and 3312 µg/g with overall mean value of 2437 µg/g. The high overall mean concentrations during winter and summer were recorded in site A followed by site B with values of 2740 and 2509 µg/g, respectively. Relatively, lower overall mean concentrations were recorded in site C with a value of 2062 µg/g.

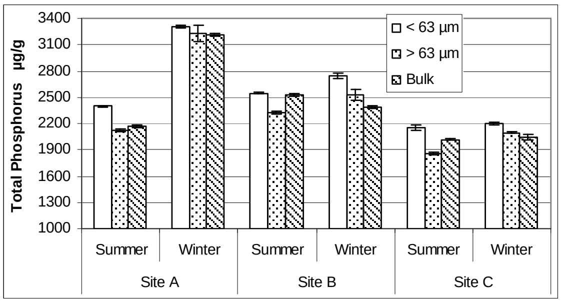

Figure 13a: Mean concentrations of TP ± SD in KTD sediments during dry (summer) and wet (winter) seasons.

The results (Fig. 13b) show also that the inorganic phosphorus (IP) ranged between 346 and 947 µg/g with overall mean value of 597µg/g. Similar to TP, The higher overall mean concentrations were recorded in the site A followed by site B with values of 615 and 606 µg/g, respectively. Comparatively lower overall mean concentrations were recorded in site C with a mean concentration of 571 µg/g. Phosphate anions can be sorbed on freshly precipitated ferric and aluminum hydroxides that may occur in the sediments (Bache and Williams, 1971). It may be transported also to sediments by settling of phytoplankton (organic particulates), settling of solid inorganic phosphorus (apatites), and settling of clays containing adsorbed phosphorus (Furumai, 1989). According to Brady (1990), 98-99% of phosphorus is associated with primary or secondary minerals and with organic matter. This can explain the presence of the relatively high concentrations of TP and IP in the sediments of sites A and B which contain high concentration of OM as compared with site C.

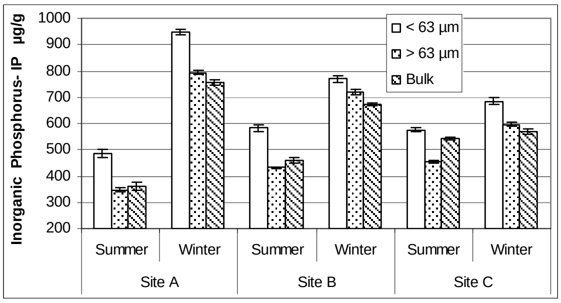

Figure 13b: Mean concentrations of IP ± SD in KTD sediments during dry (summer) and wet (winter) seasons.

The less than 63 µm sediment fraction contained the higher concentrations of IP and TP which can be at least partly attributed to its higher contents of organic matter compared to the >63 µm fraction. Seasonally, highest values of IP and TP were recorded in winter which can be attributed to the weathering of rocks and erosion of soils of the catchment area, agricultural runoffs, and industrial effluents which normally contain high concentrations of phosphorus. The ANOVA test (Table 5) showed significant differences in TP between sites and between seasons. By comparison, there were no significant differences in IP concentration between sites, but there was significant difference between seasons. The difference in TP and IP concentrations between fractions was significant in summer but not in winter. A result that need more investigation.

Table (4): Mean concentration of nutrients (µg/g) and organic matter (%) in the sediments of King Talal Dam during summer and winter time.

Site	Fraction	Season		Organic Matter	Total Nitrogen	Total Phosphorus	Inorganic Phosphorus	Organic Phosphorus
Mid Point of the Dam (A)	**<63 µm**	Summer	$\bar{X}$ ±S.D	2.5±0.30	9603±8	2400±7.10	485±14.80	1916±3.60
		Winter	$\bar{X}$ ±S.D	8.7±0.10	11604±5	3312±16.30	947±10.40	2365±15
	>63 µm	Summer	$\bar{X}$ ±S.D	0.5±0.15	7762±15	2120±14	346±7.80	1775±5
		Winter	$\bar{X}$ ±S.D	6.1±0.20	9642±28	3233±62	794±6.10	2439±11
	Bulk	Summer	$\bar{X}$ ±S.D	0.75±0.03	9189±10	2168±10.60	361±16.30	1807±10
		Winter	$\bar{X}$ ±S.D	7.25±0.07	8982±14	3211±15.60	756±8	2455±14
Deepest Point of the Dam (B)	**<63 µm**	Summer	$\bar{X}$ ±S.D	1.5±0.08	7128±11.50	2548±10.70	583±12.80	1965±10.50
		Winter	$\bar{X}$ ±S.D	7.5±0.05	10626±38	2753±31	769±11.30	1984±9.10
	>63 µm	Summer	$\bar{X}$ ±S.D	0.25 ± 4^{-1}	4580±13	2320±15	432±2.90	1888±8
		Winter	$\bar{X}$ ±S.D	5.9±0.10	8591±3	2528±67.20	718±11.30	1810±4.20
	Bulk	Summer	$\bar{X}$ ±S.D	0.51±0.06	6658±12	2523±17.70	461±10.20	2062±3.40
		Winter	$\bar{X}$ ±S.D	5.95±0.07	6947±6.60	2383±17	674±5.80	1708±18
Intake Point of the Dam (C)	**<63 µm**	Summer	$\bar{X}$ ±S.D	2±0.16	6344±7	2155±28.30	576±6.40	1580±14
		Winter	$\bar{X}$ ±S.D	6.1±0.14	8940±53	2195±14	686±13.40	1510±12.20
	>63 µm	Summer	$\bar{X}$ ±S.D	0.5±0.06	3459±11.40	1857±16.30	454±7.50	1402±14.50
		Winter	$\bar{X}$ ±S.D	5.1±0.07	8247±15	2095±7.10	597±10	1498±16
	Bulk	Summer	$\bar{X}$ ±S.D	0.53±0.06	4480±11	2020±14.20	543±5.70	1477±14.80
		Winter	$\bar{X}$ ±S.D	5.7±0.05	7567±6.30	2048±30.10	569±12.70	1479±9.20

$\bar{X}$: Mean. S.D: Standard Deviation.

Table (5): P-Values of nutrients and other chemical species in KTD sediments.

	Between sites	Between Fractions		Between seasons
		Summer	Winter	
OM %	0.72 (N.S)	<0.0001 (S)	0.002 (S)	<0.0001 (S)
Total Phosphors	<0.0001 (S)	0.04 (S)	0.6 (N.S)	0.0032 (S)
Inorganic Phosphorus	0.78 (N.S)	0.002 (S)	0.1 (N.S)	<0.0001 (S)
Total Nitrogen	0.0009 (S)	0.04 (S)	0.01 (S)	0.0002 (S)

(S): Significant (N.S): Not Significant

3.5. Comparison With Previous Studies:

Table (6) shows that the results of dissolved oxygen, nitrate, nitrite, ammonia and total nitrogen are either in agreement with or within the range of the results of the RSS (2005). The pH and water temperature results are within the range reported by the RSS (2005) and Mahasneh and Soub (1983). Transparency values are in agreement with the lower values reported by Mahasneh and Soub (1983). Table 6 shows that the concentrations ranges of total nitrogen and total phosphorus in the sediments of the present study are larger than the ranges reported by the RSS (1992). The high concentrations of nutrients in the present study are attributed to the increased industrial and wastewater effluents and increased load of nutrients in Amman-Zarqa area as well as to increased agricultural activities in the area.

Table (6): Comparing of water (mg/l) and sediments (μg/g) results with previous studies on KTD.

Phase	Year Element	Mahasneh and Soub (1983)	RSS 2005 (Dam Center)	This Study		
				Site A	Site B	Site C
Water	pH (SU)	6.5-90	7.51-8.33	7.77	7.91	7.91
	Temperature ºC	12-32	12.1-27.30	17.60	15.90	16.80
	DO (mg/l)	-------	0.5-7.30	5	4.70	4.66
	Transparency (m)	0.6-60	------	0.72	0.67	0.59
	Nitrate (mg/l)	-------	<0.05-16.20	17.20	14	16.60
	Nitrite (mg/l)	-------	0.01-2.45	1.50	1.39	1.45
	Ammonia (mg/l)	-------	13-27	11.80	16.90	14
	Total Nitrogen (mg/l)	-------	17-38	31.80	35.50	34.90
	Total Phosphorus (mg/l)	-------	4.3-7.80	5.60	5.50	5
Sediments			**RSS 1992**			
		--------		Site A	Site B	Site C
	Total Phosphorus (μg/g)	--------	234-1981	2740	2509	2062
	Total Nitrogen (μg/g)	--------	78-4810	9464	7422	6506

Table (7) shows the correlation coefficient between nutrients in water and sediments. TN in surface water shows weak correlation with TN and TP in sediments, while TP in water shows high correlation with TN and TP in the same sediment samples. In contrast, TN in the near-bottom water shows negative correlation with TN and TP in sediments, while TP in the near-bottom water shows weak correlation with TN and TP in the same sediments samples.

Table (7): Correlation coefficient between nutrients in water and sediments of KTD.

Phase		Nutrients in sediments	
		TN	TP
Nutrients in surface water	TN	0.08	0.31
	TP	0.60	0.82
Nutrients in near-bottom water	TN	-0.54	-0.70
	TP	-0.24	0.005

4. Conclusions:

Temperature, pH, Do, and nitrate values in the surface water were higher than those of the near-bottom water. Temperature of the surface water ranged between 13.30 ˚C during winter and 28.90 ˚C during summer. By comparison, near-bottom water temperature ranged between 8.30 ˚C during winter and 17.10 ˚C during summer. Dissolved oxygen is low in the near-bottom water (1.10 mg/l) when compared with that in the surface water 13.90 mg/l. The high values of DO in surface water are mainly attributed to the direct contact of the surface water with air and to the effect of photosynthetic activity. The high DO values in winter is attributable to relatively low temperature of water and high input of floodwater that contains high oxygen due to its possible mixing with atmospheric oxygen. The levels of pH, temperature, DO, in KTD water vary significantly during different seasons. The generally higher concentration of nitrate in the surface water can be attributed to the higher nitrification rate that usually occur at this level, while the generally higher ammonia concentration in the near-bottom water is due to the higher denitrification rate that prevails at this level. The concentrations of nitrogen and phosphate species entering KTD reservoir are affected mainly by the input of nitrogen and phosphorus from Zarqa River and Wadi Rmemeen both of which receives effluents from major wastewater treatment plants. High concentrations of phosphorus and total phosphorus in KTD water were recorded in winter, due to rainwater that carries soil erosion products and agricultural waste.

The concentrations of nutrients and organic matter are higher in the clay–silt size fraction (<63μm) of the sediments. They showed more or less similar general trend of spatial distribution, where maximum values occurred during winter. Most pollutants decrease towards the far end of the dam (outlet point). The statistical examination of nutrients results in water and sediments showed that the spatial and depth differences are apparent and insignificant which is attributed to the fact that King Talal Dam is a small body of water with no big depth difference between its surface and bottom. Most of the measured species showed significant temporal variation.

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