

Spatiotemporal Water Quality Assessment of Dumate Al-Jandal Lake (KSA) Using Environmetric Techniques

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Abstract

Environmentally, the objective of the study conducted in evaluating the spatiotemporal water quality assessment using some statistical techniques. Physicochemical characteristics determination applied on Dumate al-Jandal Lake, whether the analysis of water quality is good for agricultural irrigation or other ecosystem services. Sampling and measurements were taken weekly at five sites started from February 2009 to January 2011. Descriptive analysis as well as the 95% confidence intervals, Wilks' Lambda Statistics, MANOVA and ANOVA showed no presence of significant difference at the level of $p < 0.05$ among seasons and between sites, except the mean effect only for some parameter like Iron on the physicochemical parameters whereas a significant difference among the mean of physicochemical characteristics of water data to sites for the parameters like pH and nitrate, while there are no differences among the mean of physicochemical characteristics of water data of sites for the other parameters. Multiple comparison t-test shows the differences between means Sites of (1, 3) and (2, 5) as well as between (3) and (5) for the parameter pH. Results showed a significant difference at ($p < 0.05$) between the means of Site (1) and all Sites (3, 4 and 5) as well as between Site (2) and (3) for nitrate, but a significant difference at ($p < 0.05$) among the mean associated with seasons for temperature, electrical conductivity, specific density, sulphate, nitrite, ammonia, chloride, total hardness, total alkalinity, manganese, magnesium and calcium hardness, while there are no differences among the mean of seasons for the other parameters. Whereas results of multiple comparison t-test showed that a differences between the means of season (i) and season (j), for each parameter. The study concluded that some of physicochemical parameters were reflected the presence of pollutants and absence of good ecosystem activities. To avoid seasonal pollution, water lake management are recommended.

Keywords: Physicochemical analysis, Aquatic ecosystem, Environmetric Techniques.

1. Introduction

Dumate al-Jandal has a large lake, located about 6 km away western town Dumate Al-Jandal in Al-Jouf Province of Saudi Arabia. The storage capacity of the lake is about 10 million cubic meters of water and annually evaporates the same amount of nutrition. Its surface area is estimated of about one million one hundred thousand square meters with about 8 kilometers varying depth and approximately 1.10 million m^2 and lake level is 643 m which is about 585 m above the sea level. Its surface area is about 8 km with various depths. From northern reservoir, the water pumps through large pipes directly to the lake so weathering changes besides linkages seasonal variation in precipitation, surface runoff, interflow have a strong effect on the concentration of pollutants which affect lake water quality [1]. Due lack of good water quality information about the lake, protection of its water resources becomes topmost priority. In this study spatiotemporal analysis and Research-wise, one of the important stages in the protection and conservation of these resources of water and quality of the aquatic ecosystems [2]. In general, water quality is strongly related with physical, chemical and biological characteristics which are determined the healthy status of any aquatic ecosystem [3]. Therefore, quality of water assessment in any ecosystem requires significant information about the available resources for supporting ecosystem life [4]. Because the physicochemical characteristics of water resources are affected their species composition, productivities and abundance, therefore, this study was conducted to understand the physicochemical properties of the artificial lake for different types of ecosystem services and activities for one year from February 2009 to January 2011 [5].



The statistical measures of environmental data make spatiotemporal variations of water quality often difficult to interpret, so statistical approaches like descriptive of minimum, maximum, mean and standard deviation values as well as the 95% confidence intervals are used in this study for providing a reliable analysis to summarize these data for each parameter to all sites and seasons [6]. Also, Wilks' Lambda Statistics in the Multivariate Analysis of Variance (MANOVA) techniques have been widely used as unbiased methods in analysis of water quality and for evaluating sites and seasons which have mean effect parameter on the physiochemical of water [7]. One Way Analysis of Variance (ANOVA) and the results of multiple comparison t-test techniques will be used to show if there are differences among the mean of physiochemical characteristics of water data of sites that drawing out meaningful conclusions [8].

Physical parameters such as temperature, acidity, turbidity and others have known to affect in ecosystem as result of the interaction of both physical and chemical properties of water which plays a significant role in the composition. Also, it is a great environmental concern since it one of the major available water resources for animal and agricultural irrigation consumption. Until now no previously available data on the chemical, physical properties reported on the lake, which is the primary purpose of this study to fill this gap [9]. The major objective of this research study focusing into the relationship between the results of 22 parameters and their spatiotemporal environmental variations which determining water quality productivity and a new methodology for examining the impact of all the sources of pollution in the lake and to identify the parameters responsible for spatiotemporal variability in water quality using.

2. Materials and Methods

2.1 Study Area

The present study was carried out on the largest and only artificial lake in Dumate Al-Jandal city, that located in the northern part of the Arabian Peninsula in Saudi Arabia, that fed from the surplus of agricultural irrigation water through northern and southern major reservoirs in the city, which is one of the richest regions of the kingdom with ground water that pumped to it. Water samples were taken from surface of different locations in the lake as seen in Fig.1 and Fig. 2.



Figure 1: Satellite image of lake Dumate Al-Jundal -KSA.

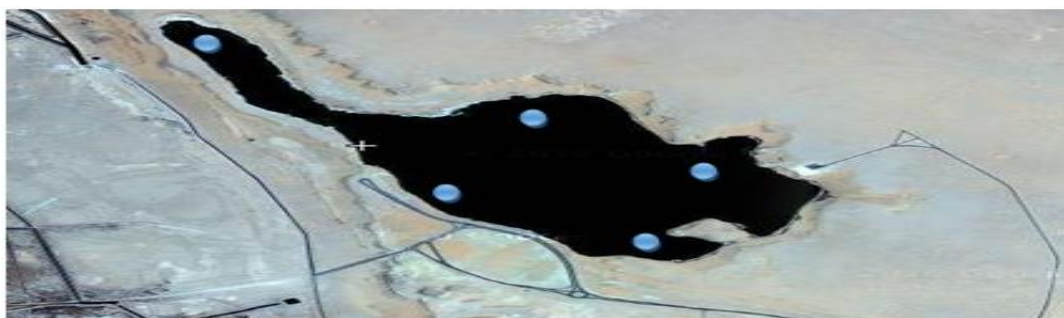


Figure 2: Location of the study monitoring stations area in the Dumate Al-Jundal lake-KSA

2.1. Sampling and Analysis

Water samples were collected weekly from five sampling sites between 11.00 and 1.00 O'clock a day, from February 2009 to January 2010. Then water samples collected from each site placed in one-liter polyethylene pre-rinsed with acid, filtered with a 0.45 µm membrane using vacuum filtration apparatus and add a few drops of 36% HCl to keep pH less than two and refrigerated at 4 °C for the laboratory analysis. Physical parameters like temperature, conductivity and pH, were determined respectively on the spot using a thermometer (± 0.10 °C), pH meter (*model HANNA*), and an electric conductivity meter (*model Bischof L17*). While other chemical parameters such as total alkalinity, total hardness, calcium, magnesium, sulfate, nitrite, nitrate, ammonia and phosphate were determined in the laboratory within 24 - 48 hours of sampling according to standard methods of *Parsons et al. (1984)* and *Golterman and Clymo (1969)* and *APHA (1998)* [10-11].

2.2. Statistical Analysis

To simplify studying seasonal effect on water lake quality, the whole observation period was divided into four fixed seasons: Spring (March, April, May), Summer (June, July, August), Autumn (September, October, November), and Winter (December, January, February). Twenty-two different physicochemical parameters like temperature, pH, turbidity, electrical conductivity, specific density, total dissolved solids, total hardness, silica, phosphate, sulphate, nitrite, nitrate, ammonia, chloride, total alkalinity, magnesium hardness, calcium hardness, aluminum, iron, manganese, ozone and radical chloride were all examined. In this study, the use of descriptive statistical analysis is a must to determine minimum value, maximum value, mean and standard deviation as well as the 95% confidence intervals for exploring whether there is present any significant relationship among water quality parameters and between sites.

2.3. Descriptive and Multivariate Statistical Methods

Data results of water samples presented in terms of descriptive analysis for evaluating the seasonal trends between months and some environmetric techniques such as ANOVA, MANOVA and the results of multiple comparison t-test that are used to evaluate the impact of organism and their environment anthropogenic activities on spatiotemporal variations of physicochemical characteristics of the lake. Three multivariate methods were applied to spatiotemporal water quality assessment of the lake. First, Wilks' Lambda Statistics in the MANOVA techniques which have been widely used as unbiased methods in analysis of water quality data and for evaluating sites and seasons which have mean effect factor on the physiochemical of water. Second, ANOVA ($p < 0.05$) level of significance was used also to analyzing and evaluating significant differences among the sites for all variables of water quality. Third, the results of multiple comparison t-test techniques was used to find out if there are differences among the mean of physiochemical characteristics of water data due to sites and seasonal variation that drawing out meaningful conclusions. ANOVA technique explore sets of variables with similar properties and successfully allowing to simplify description of data observations and to enable to find out the structure or patterns in the presence of confusing data. SPSS (version. 22) software was used to perform for a statistical analyses and their applications. Simply, to explore the differences between the means of different sites and for describing the temporal variations of the observed water quality parameters. Also, specific various physicochemical parameters carried out in order to recognize the nature and magnitude of the relationship among them [12-13].

3. Results and Discussion

Physicochemical analysis and their original data measurements in seasons and sites are summarized in Table 1. Sites 1 and 4 has a higher and lower temperature in winter seasons respectively, whereas in spring seasons site 3 and 1. In summer sites 3 and 4 indicated the higher and lower values while sites 1 and 2 showed the higher and lower values. pH parameters showed in winter a higher and lower values at sites 3 and 2 while sites 3 and 5 showed the higher and lower values respectively. Sites 2 and 5 the higher value and lower values in Autumn, also sites 4 and 2 as well. Turbidities in winter appear very high at site 1 and very in site 2 in contrast in spring season sites 2 seem to be very low and the highest value appeared in site 4. In summer and autumn seasons

value appeared very high in sites 4 and 2 whereas the lowest have been seen in sites 5 and 5 respectively. Electrical conductivity has showed higher values at sites 1 and lower at site 4 in winter, but sites 3 showed a higher value while site 4 showed a lower value. Summer the higher value shown at site 1 but the lower value at site 3. In autumn site 1 has shown higher value while site 2 has the lowest value. Physical specific density parameter has shown the higher values in winter, spring, summer and autumn at two sites 2 and 3, in addition to 3, 3 and two sites 1 and 3, while the lowest values have been seen at sites 5, 5, 2, 5 respectively. Finally, the total dissolved solids have shown the higher values in winter, spring, summer and autumn at sites 5, 1, 5 and 3, while the lowest values have been seen at sites 1, 3, 4 and 1 respectively.

Table 1: Physicochemical characteristics of water of Dumate Al-Jundal lake (February 2009 to January 2011)

S. no.	Parameters	Seasons	Site 1	Site 2	Site 3	Site 4	Site 5
1	Temperature °C						
	winter (December, January, and February)	Winter	16.10	16.50	15.70	15.20	15.70
	spring (March, April, and May)	Spring	19.50	21.60	22.20	19.90	21.60
	summer (June, July, and August),	Summer	23.30	23.70	24.60	23.80	22.90
	autumn (September, October, and November),	Autumn	22.50	18.70	21.50	19.60	21.40
2	pH						
	winter (December, January, and February)	Winter	8.21	8.11	8.45	8.29	8.13
	spring (March, April, and May)	Spring	8.15	8.34	8.44	8.19	8.10
	summer (June, July, and August),	Summer	8.11	8.30	8.25	8.17	8.09
	autumn (September, October, and November),	Autumn	8.04	8.22	8.09	8.15	8.01
3	Turbidity (NTU)						
	winter (December, January, and February)	Winter	2.92	2.09	2.61	2.57	2.11
	spring (March, April, and May)	Spring	2.71	1.93	2.15	2.87	2.55
	summer (June, July, and August),	Summer	2.45	2.42	2.38	2.60	2.28
	autumn (September, October, and November),	Autumn	2.79	5.22	2.93	2.81	2.77

4	Electrical conductivity ($\mu\text{S}/\text{cm}$)						
	winter (December, January, and February)	Winter	48549	48237	48390	48227	48387
	spring (March, April, and May)	Spring	48530	47090	45990	45290	45984
	summer (June, July, and August),	Summer	48640	48410	48172	49272	48262
	autumn (September, October, and November),	Autumn	49610	48780	48907	48997	48837
5	Specific density						
	winter (December, January, and February)	Winter	1.033	1.034	1.034	1.032	1.031
	spring (March, April, and May)	Spring	1.032	1.031	1.033	1.034	1.030
	summer (June, July, and August),	Summer	1.034	1.032	1.034	1.033	1.033
	autumn (September, October, and November),	Autumn	1.035	1.035	1.035	1.034	1.033
6	Total dissolved solids (mg/L)						
	winter (December, January, and February)	Winter	49532	52620	49550	49562	52670
	spring (March, April, and May)	Spring	52440	50670	48740	50670	48780
	summer (June, July, and August),	Summer	52440	52050	51920	49532	52620
	autumn (September, October, and November),	Autumn	45090	49550	50739	49540	50639
7	Silica (SiO_4^-) (mg/L)						
	winter (December, January, and February)	Winter	8.40	6.60	7.30	7.40	7.50
	spring (March, April, and May)	Spring	8.10	11.6	8.30	8.20	8.15
	summer (June, July, and August),	Summer	11.3	5.20	5.10	5.12	5.90
	autumn (September, October, and November),	Autumn	8.20	7.30	7.50	7.40	7.48

8	Phosphate (PO_4^-) (mg/L)						
	winter (December, January, and February)	Winter	0.75	0.57	0.64	0.65	0.61
	spring (March, April, and May)	Spring	0.80	0.66	0.66	0.65	0.64
	summer (June, July, and August),	Summer	0.42	0.55	0.67	0.67	0.63
	autumn (September, October, and November),	Autumn	0.67	0.73	0.49	0.51	0.48
9	Sulphate (SO_4^-) (mg/L)						
	winter (December, January, and February)	Winter	1600	1640	1767	1757	1769
	spring (March, April, and May)	Spring	1903	2245	1540	1520	1530
	summer (June, July, and August),	Summer	960	810	990	993	986
	autumn (September, October, and November),	Autumn	1552	1109	930	986	979
10	Nitrite (NO_2^-) (mg/L)						
	winter (December, January, and February)	Winter	0.048	0.018	0.021	0.019	0.020
	spring (March, April, and May)	Spring	0.015	0.014	0.011	0.013	0.012
	summer (June, July, and August),	Summer	0.017	0.020	0.018	0.017	0.014
	autumn (September, October, and November),	Autumn	0.050	0.072	0.061	0.055	0.064
11	Nitrate (NO_3^-) (mg/L)						
	winter (December, January, and February)	Winter	2.1	1.3	1.1	1.0	1.1
	spring (March, April, and May)	Spring	1.6	1.4	0.9	1.01	1.2
	summer (June, July, and August),	Summer	1.1	1.3	0.7	1.1	0.90
	autumn (September, October, and November),	Autumn	1.1	1.3	0.9	1.2	1.1
12	Ammonia (NH_3) (mg/L)						

	winter (December, January, and February)	Winter	0.09	0.05	0.08	0.07	0.08
	spring (March, April, and May)	Spring	0.04	0.11	0.08	0.06	0.07
	summer (June, July, and August),	Summer	0.09	0.13	0.25	0.09	0.18
	autumn (September, October, and November),	Autumn	0.15	0.07	0.05	0.06	0.12
13	Chloride (mg/L)						
	winter (December, January, and February)	Winter	15476	11930	12920	11730	12320
	spring (March, April, and May)	Spring	14600	16500	15350	15251	14358
	summer (June, July, and August),	Summer	14900	35400	32300	35411	32322
	autumn (September, October, and November),	Autumn	16100	17800	13800	17848	13870
14	Total hardness (CaCO ₃ mg/l)						
	winter (December, January, and February)	Winter	15476	6360	5340	5360	6340
	spring (March, April, and May)	Spring	4683	2660	8050	5660	7050
	summer (June, July, and August),	Summer	7850	4730	8026	7730	7826
	autumn (September, October, and November),	Autumn	16100	17800	13800	14730	14026
15	Total alkalinity (CaCO ₃ /L)						
	winter (December, January, and February)	Winter	450	295	315	301	319
	spring (March, April, and May)	Spring	320	340	600	349	330
	summer (June, July, and August),	Summer	650	710	702	700	705
	autumn (September, October, and November),	Autumn	750	500	800	550	504

16	Magnesium Hardness (mg/L)						
	winter (December, January, and February)	Winter	5838	1405	1584	1838	1455
	spring (March, April, and May)	Spring	2291	5420	6320	5920	6358
	summer (June, July, and August),	Summer	8300	7452	6830	7487	6839
	autumn (September, October, and November),	Autumn	5630	7840	7340	7878	7396
17	Calcium Hardness (mg/L)						
	winter (December, January, and February)	Winter	1974	3205	4120	3145	4122
	spring (March, April, and May)	Spring	4625	2010	1423	2000	1451
	summer (June, July, and August),	Summer	2430	1390	1700	1395	1770
	autumn (September, October, and November),	Autumn	1050	1850	1654	1750	1647
18	Aluminum (Al) ($\mu\text{g}/\text{L}$)						
	winter (December, January, and February)	Winter	0.012	0.009	0.013	0.009	0.013
	spring (March, April, and May)	Spring	0.039	0.011	0.012	0.011	0.012
	summer (June, July, and August),	Summer	0.007	0.009	0.016	0.009	0.016
	autumn (September, October, and November),	Autumn	0.008	0.011	0.015	0.011	0.015
19	Iron (Fe) ($\mu\text{g}/\text{L}$)						
	winter (December, January, and February)	Winter	0.14	0.04	0.03	0.04	0.03
	spring (March, April, and May)	Spring	0.05	0.10	0.06	0.10	0.06
	summer (June, July, and August),	Summer	0.07	0.07	0.11	0.07	0.11
	autumn (September, October, and November),	Autumn	0.05	0.11	0.12	0.11	0.12

20	Manganese (Mn) ($\mu\text{gm/L}$)						
	winter (December, January, and February)	Winter	0.003	0.008	0.003	0.008	0.003
	spring (March, April, and May)	Spring	0.01	0.007	0.002	0.007	0.002
	summer (June, July, and August),	Summer	0.003	0.002	0.003	0.002	0.003
	autumn (September, October, and November),	Autumn	0.002	0.001	0.002	0.001	0.002
21	Ozone(O_3) ($\mu\text{gm/L}$)						
	winter (December, January, and February)	Winter	0.0	0.0	0.0	0.0	0.0
	spring (March, April, and May)	Spring	0.0	0.0	0.0	0.0	0.0
	summer (June, July, and August),	Summer	0.0	0.0	0.0	0.0	0.0
	autumn (September, October, and November),	Autumn	0.0	0.0	1.20	0.0	0.0
22	Cl ($\mu\text{gm/L}$) radical						
	winter (December, January, and February)	Winter	0.0	0.0	0.0	0.0	0.0
	spring (March, April, and May)	Spring	0.0	0.0	0.0	0.0	0.0
	summer (June, July, and August),	Summer	0.0	0.0	0.0	0.0	0.0
	autumn (September, October, and November),	Autumn	0.0	0.0	0.0	0.0	0.0

The chemical parameters like silica indicated the higher values in winter, spring, summer and autumn at sites 1, 2, 1 and 1, while the lowest values have been seen at sites 2, 1, 2 and 2 respectively. Also, phosphate indicated the higher values in winter, spring, summer and autumn at sites 1, 1, 3 and 4 and 2, while the lowest values have been seen at sites 5, 5, 1 and 5 respectively. Sulphate indicated the higher values in winter, spring, summer and autumn at sites 4, 2, 4 and 1, while the lowest values have been seen at sites 1, 4, 2 and 3 respectively. Nitrite indicated the higher values in winter, spring, summer and autumn at sites 5, 1, 3 and 2, while the lowest values have been seen at sites 2, 3, 1 and 4 and 1 respectively. Nitrate indicated the higher values in winter, spring, summer and autumn at sites 1, 1, 2 and 2, while the lowest values have been seen at sites 4, 3, 3 and 3 respectively. Ammonia indicated the higher values in winter, spring, summer and autumn at sites 1, 2, 3 and 1, while the lowest values have been seen at sites 2, 1, 1 and 4 and 3 respectively. Chloride indicated the higher values in winter, spring, summer and autumn at sites 1, 3, 4 and 4, while the lowest values have been seen at sites 4, 5, 1 and 5 respectively. Total hardness indicated the higher values in winter, spring, summer and autumn

at sites 1, 3, 3 and 2, while the lowest values have been seen at sites 3, 2, 2 and 3 respectively. Total alkalinity indicated the higher values in winter, spring, summer and autumn at sites 1, 3, 2 and 1 while the lowest values have been seen at sites 2, 1, 1 and 2, respectively. Magnesium Hardness indicated the higher values in winter spring, summer and autumn at sites 1, 5, 1 and 4 while the lowest values have been seen at sites 2, 1, 3 and 1 respectively. Calcium hardness indicated the higher values in winter, spring, summer and autumn at sites 5, 1, 1 and 2 while the lowest values have been seen at sites 1, 3, 2 and 1, respectively. Aluminum indicated the higher values in winter, spring, summer and autumn at sites 5, 1, 3 and 5 and 3 and 5 while the lowest values have been seen at sites 2 and 4, 2, 4 and 2 and 4 respectively. Iron indicated the higher values in winter, spring, summer and autumn at sites 1, 3, 5, 1 and 3, 5 while the lowest values have been seen at sites 3, 5, 1, 2, 4 and 1 respectively. Manganese indicated the higher values in winter, spring, summer and autumn at sites 1, 3, 5, 2, 4, 2, 4 and 2 while the lowest values have been seen at sites 2, 4, 1, 2, 4, 2, 4 and 2 respectively. While ozone and chloride radical showed zero values.

3.1. Physical parameters

The descriptive analysis data of the physical parameters, Table 2 and Fig. 3, 4 shows, maximum and minimum temperature values were recorded 24.6 - 15.2 °C with mean 20.30 °C respectively. The warmest temperature was noticed at August in summer and the coldest at January in winter seasons. Buffering capacity (pH) of a lake that measure its relative acidity or alkalinity exhibit wide variations, not only in actual pH values, but also in the amount of dissolved materials that impact pH which was ranged from 8.010 to 8.450 with the highest values in spring season and the lowest in autumn season at most of the study sites. For instance, the pH values at site 5 of the lake showed a trend decreasing from wet to dry season, while it becomes higher during the dry season. The reason behind extensive variations was due to the limestone, which contributes calcium carbonate to the water of the lake, so the mean of total hardness (CaCO₃) is about 6860.023 mg/L responsible for the excellent buffering capacity of the lake.

Table 2: Statistical measurements for the physiochemical parameters data of water samples.

Parameter	N	Minimum	Maximum	Mean	Std. Deviation	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
Temperature °C	20	15.200	24.600	20.30000	3.050453	18.87234	21.72766
pH	20	8.010	8.450	8.19200	.121940	8.13493	8.24907
Turbidity (NTU) Nephelometric Turbidity Units	20	1.930	5.220	2.65800	.671343	2.34380	2.97220
Electrical conductivity ($\mu\text{S}/\text{cm}$)	20	45290.000	49610.000	48128.05000	1145.979860	47591.71492	48664.38508
Specific density (mg/ml)	20	1.030	1.035	1.03310	.001410	1.03244	1.03376
Total dissolved solids (mg/L)	20	45090.000	52670.000	50467.70000	1871.697347	49591.71868	51343.68132
Silica (SiO_4^-) (mg/L)	20	5.100	11.600	7.60250	1.692665	6.81031	8.39469
Phosphate (PO_4^-) (mg/L)	20	.420	.800	.62250	.094806	.57813	.66687
Sulphate (SO_4^-) (mg/L)	20	810.000	2245.000	1378.30000	412.220061	1185.37507	1571.22493

Nitrite (NO ₂ ⁻) (mg/L)	20	.011	.072	.02895	.020451	.01938	.03852
Nitrate (NO ₃ ⁻) (mg/L)	20	.700	2.100	1.17050	.297241	1.03139	1.30961
Ammonia (NH ₃) (mg/L)	20	.040	.250	.09600	.050513	.07236	.11964
Chloride (mg/L)	20	11730.000	35411.000	18509.30000	8080.371670	14727.56965	22291.03035
Total hardness (CaCO ₃) (mg/L)	20	2660.000	17800.000	8979.85000	4529.391574	6860.02949	11099.67051
Total alkalinity (CaCO ₃) (mg/L)	20	295.000	800.000	509.50000	179.685837	425.40444	593.59556
Magnesium Hardness (mg/L)	20	1405.000	8300.000	5571.05000	2417.771603	4439.49806	6702.60194
Calcium Hardness (mg/L)	20	1050.000	4625.000	2235.55000	1038.068524	1749.71898	2721.38102
Aluminum (Al) (µgm/L)	20	.007	.039	.01290	.006672	.00978	.01602
Iron (Fe) (µgm/L)	20	.030	.140	.07950	.034255	.06347	.09553
Manganese (Mn) (µgm/L)	20	.001	.010	.00370	.002677	.00245	.00495
Ozone(O ₃) (µgm/L)	20	.000	1.200	.06000	.268328	-.06558	.18558
Cl (µgm/L) radical	20	.000	.000	.00000	.000000	.00000	.00000

Generally, Table 1 shows the mean values of turbidities in the lake sites ranged from about 1.93 to 5.22 with mean 2.66 NTU (Nephelometric Turbidity Units). Whereas, the higher results appeared in October. Factors affecting like suspended matter or impurities include clay, silt, finely divided organic and inorganic matter, soluble colored organic compounds, plankton and other microscopic organisms might be led to higher turbidity from the lower and upper bounds at all sites but highest values associated with an Autumn seasonal cycle [13,14]. Electrical conductivity values of the lake sites Table 3, ranged from 45290.00 to 49610.00 with mean and standard deviation of 48128.05 and 1145.98 $\mu\text{S}/\text{cm}$ were reflected in general the higher values at all the sampling sites but decreases in spring season. A progressive decrease in EC in March and spring season (see Fig. 3 and 4).

Table 3: Effects (Multivariate Test Using Wilks' Statistics) of Sites and Seasons on the physicochemical parameters.

Parameter	Value	F	Sig.
Temperature oC	.162	.606 ^b	.779
pH	.030	.591 ^b	.824
Specific density	.414	1.443 ^b	.217
Total dissolved solids (mg/L)	.083	.705 ^b	.768
Silica (SiO ₄ ⁻) (mg/L)	.052	.675 ^b	.782
Phosphate (PO ₄ ⁻) (mg/L)	.012	2.379 ^b	.101
Sulphate (SO ₄ ⁻) (mg/L)	.020	2.722 ^b	.448
Nitrite (NO ₂ ⁻) (mg/L)	.063	.598 ^b	.837
Nitrate (NO ₃ ⁻) (mg/L)	.338	.719 ^b	.754
Ammonia (NH ₃) (mg/L)	.200	.787 ^b	.701
Aluminum (Al) ($\mu\text{g}/\text{mL}$)	.187	1.643 ^b	.146
Iron (Fe) ($\mu\text{g}/\text{mL}$)	.058	3.940 ^b	.002 [*]
Manganese (Mn) ($\mu\text{g}/\text{mL}$)	.379	1.621 ^b	.156
Ozone(O ₃) ($\mu\text{g}/\text{mL}$)	.905	.890 ^b	.429

*Significant at the 0.05 level.

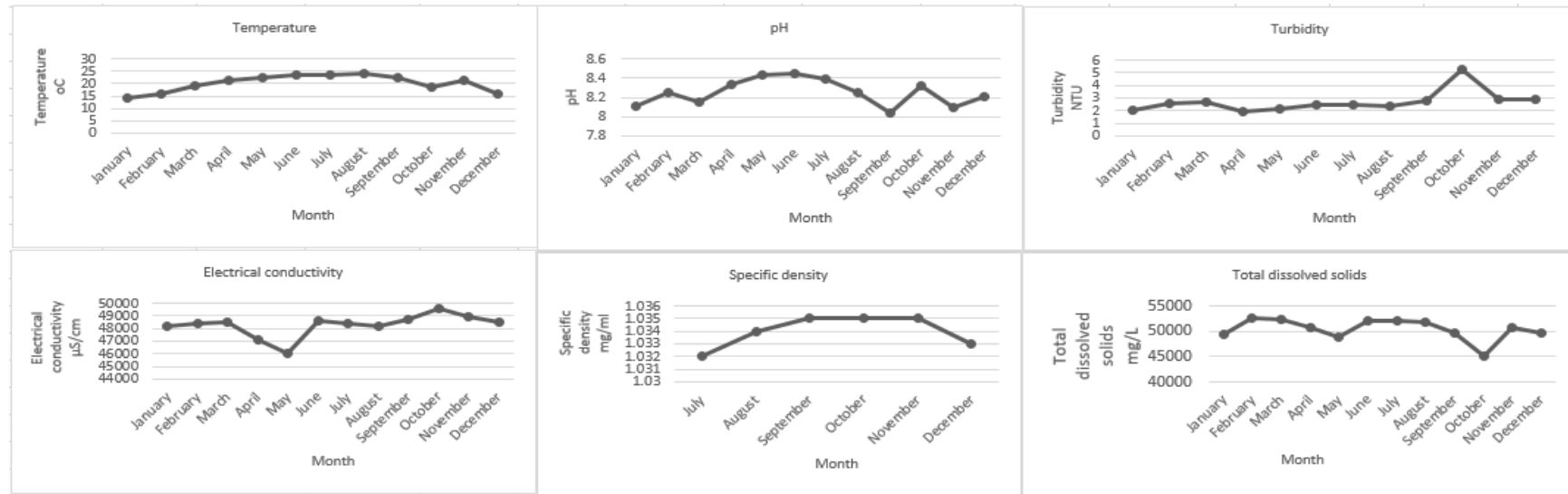


Figure 3: The mean measurements of the physical parameters according to monthly variation for all sites during February 2009 to January 2011.

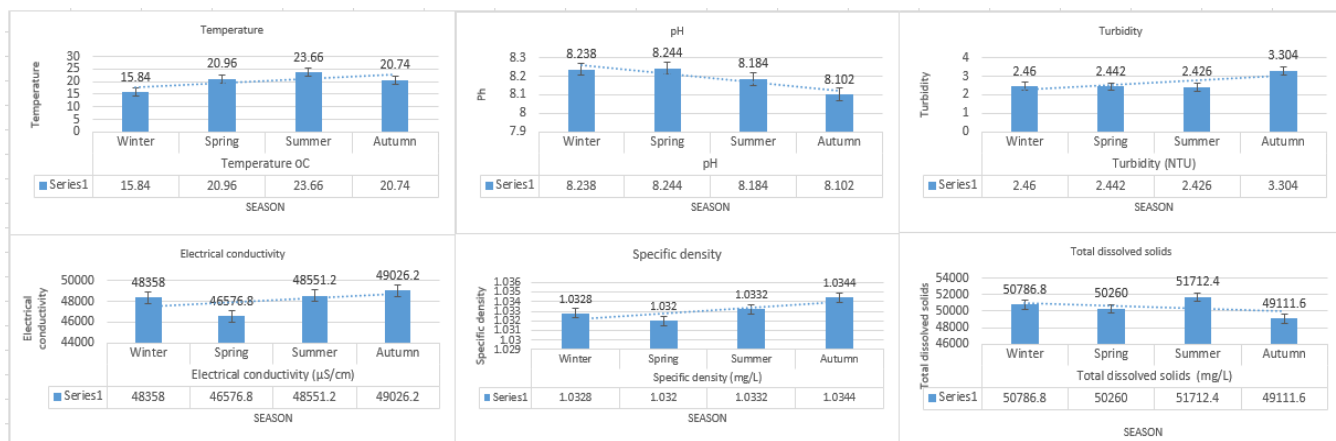


Figure 4: The mean measurements of the physical parameters according to seasonal variation for all sites during February 2009 to January 2011.

Variation in EC was significant among sites and higher values of EC were recorded in Autumn at the site 1 and lower in spring at the site 5. The reason behinds the higher results may be attributed to seasonal driven changes that associated with highly saline water of the lake. The high salt concentration of water shows that significant dissolution and /or precipitation reactions are taking place in the lake depending upon the solubility constants of different minerals present in the lake. The standard deviation of 0.00141 and mean of 1.033 of water specific density represent a significant variation at all the sites associated with a seasonal temporally changes. Maximum water specific density for the 1, 2 and 3 sites were recorded maximum of 1.035 gm/ml in autumn season and minimum in winter season (rainy season) as site 5 1.030 gm/ml. April and September showed the lowest and the maximum values whereas autumn and spring as well. Total suspended solids of the lake water ranged between minimum 45090.0 to maximum 52670.0 mg/l. The run off the agriculture wastes may be responsible for the highest values of TDS in the lake sites. Total dissolved solids show slight greater variability between seasonal cycle as indicated a lower result in spring and upper in Autumn (Fig. 3, 4).

3.2. Chemical parameters

Silica concentration was ranged from minimum 5.10 and maximum 11.60 mg/l with highest observation in April and lowest in July. Whereas, a lower results value in summer but higher in spring. Phosphate ion ranged from 0.42 -0.80 mg/L with highest values in March and lowest in June. The highest values might be due to the existences of Organic-N and total nitrogen were found in summer and winter at specific sites (Table 1 and Fig. 5, 6). On the other hand, sulphate ion was showed concentration ranged from 810.00 -2245.00 mg/l in all lake sites with highest values in April and lowest in July. Spring season indicated the higher results compared with lowest in summer. Nitrite, nitrate and ammonia are all forms of

nitrogen that can be found throughout the environmental ecosystem such as soil, air, plant and water, therefore nitrogen is an essential components of plant macronutrient that exists in many forms under study [15]. Nitrite ion was showed concentration ranged from 0.011 minimum 0.072 to maximum, specifically, January represent the lowest whereas October show the highest results as well as the lowest spring and highest in Autumn seasons. While nitrate ion was concentration ranged from minimum 0.70 to maximum 2.10, August represent the lowest whereas December show the highest results as well as the lowest summer and highest in winter seasons. But the molecular ammonia showed concentration ranged from minimum 0.040 to maximum 0.25mg/l. March was the lowest whereas September represented the highest results as well as the lowest in spring and highest values in summer seasons. In other words, slightly variation of nitrite specifically started from January to August then increased for September and October whereas the value decreased in November and December, the higher changes associated with spring as seen in Table 1 and Fig. 5 and 6. Chloride radical and ozone was not observed at all.

Significantly total hardness was ranged from 17800.00 to 2660.00 according to classification based on CaCO_3 mg/l. All lake sites indicated higher ascending of total hardness of water except March, April July and decreasing in September and December while Autumn has higher values compared with other seasons as seen in Table 1 and Fig. 5 and 6. This finding is in agreement with other studies for example on Washita River at Oklahoma (Madden and Morris, 1978) and disagree with the study on Moro Lake in Nigeria [14, 15]. Also, result of total alkalinities for all sites seemed to be high with higher mean and standard deviation 509.500 and 179.69 mg/l as seen in Table 1 and Fig. 5 and 6. Calcium carbonate (CaCO_3) precipitate is the major byproduct of the "whiting effect" [16, 17, 18]. The cause of the whiting effect, or whiting phenomenon, has not yet been fully explained by scientists. Some investigators believe warm temperatures initiate the production of phytoplankton, which causes a change in pH and results in the whiting effect. Other investigators suggest that carbonate precipitate out due to ground water flowing through carbonate containing rock limestone and discharging into surface waters, so that the results showed monthly higher ascending values except October and December whereas Spring season showed the higher values climate changes [19-20]. Concentration results of heavy metals like manganese were significantly low in all lake sites, while aluminum was totally disappeared in lake side 4 but was very low in lake sites 1, 2 and 5. Whereas results of iron concentration in all sites showed some higher ascending variations, specifically the concentration at Autumn season was slightly high compared with other seasons see Table 1 and figure 5 and 6 [21, 22].

Ions in water lake like calcium and-magnesium showed significant high concentration in different lake sites and the 95% confidence interval for lower and upper bounds of mean was ranged from 1749.72 to 2721.38 and 4439.49 to 6702.60 mg/l, respectively, also monthly increasing from January to June then decreasing from July to September was seen which means it was effected by the seasonal change. The major sources of these positive ions are from salts that have leached from mineral of soils and can also originate from anthropogenic sources, such as from road salt and agriculture run-off [23, 24, 25].

The multivariate statistical methods Wilks' Lambda is a measure of the percent variance in dependent variables not explained by differences in levels of the independent variable, Table 3 summarized the data of the physiochemical parameters. Therefore, the mean effect was tested for both dependent variables of sites and the seasons using this statistics techniques in the MANOVA test which is similar to the F-test statistic in ANOVA, then can be explored if there are differences between means of group sites among seasons for a particular combination of dependent physiochemical parameters. The data observation of water sample shows both sites and seasons have mean effect only for iron ($\text{Fe } \mu\text{gm/L}$) parameter on the physiochemical of water data. Whereas, there are no effects for the other parameters. Note that some of the parameters are not appear in the table due to their small values and zero observations as seen in Table 1 for ozone and chloride radical parameters. For this reason, the use of the ANOVA procedures was required for testing each dependent variables individually at the site and the season. The test of the existence of the mean differences among the physiochemical characteristics of water data based on sites like the multiple comparisons test to test the differences between the sites for each parameter.

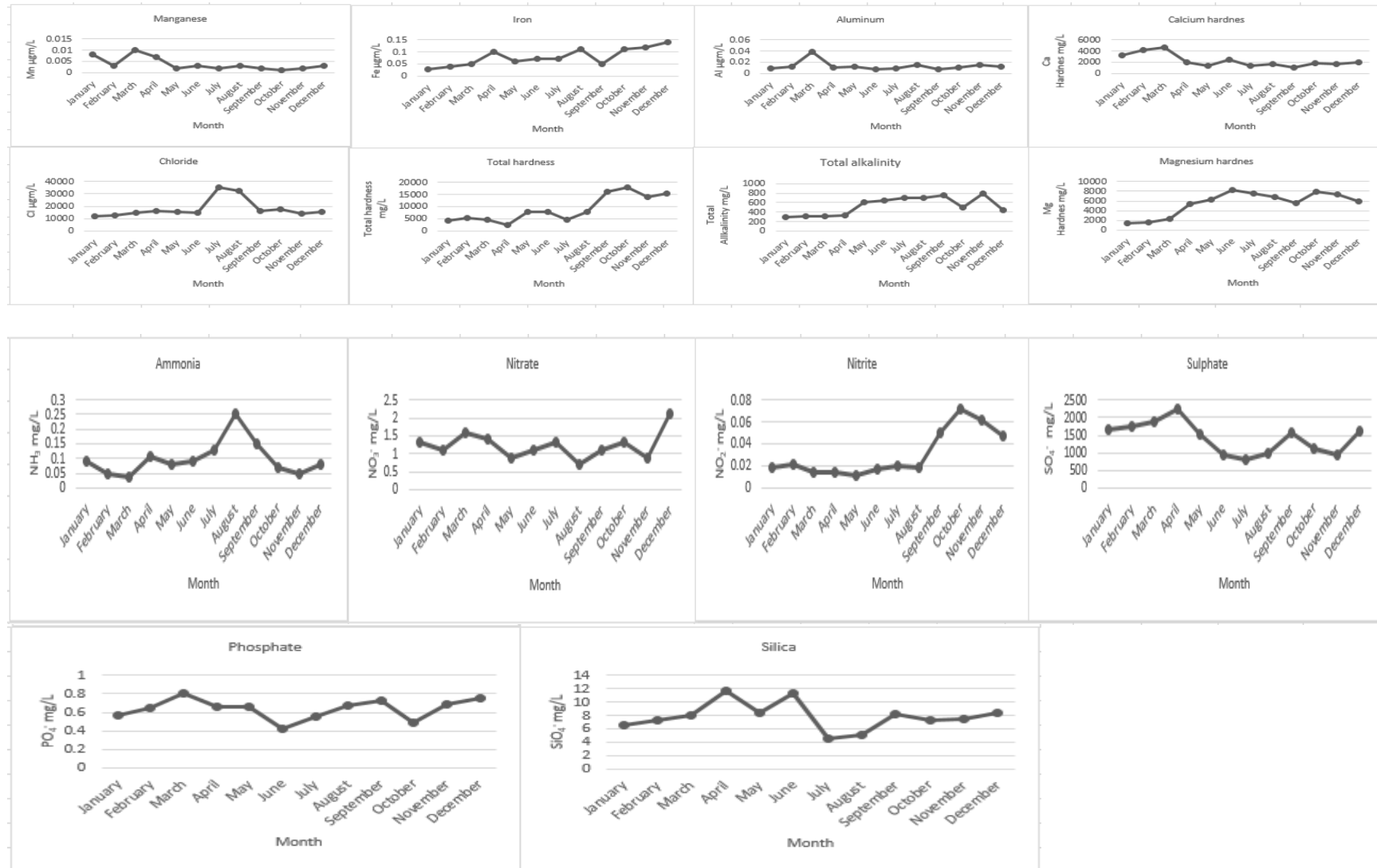


Figure 5: The mean concentrations of the chemical parameters according to monthly variation for all sites during February 2009 to January 2011.



Figure 6: The mean concentrations of the chemical parameters according to seasonal variation for all sites during February 2009 to January 2011.

Table 4: One-Way ANOVA for the mean differences of data samples according to sites for each parameter.

Parameter	F	Sig.
Temperature oC	.086	.986
pH	3.125	.047*
Turbidity (NTU)	.273	.891
Electrical conductivity ($\mu\text{S}/\text{cm}$)	.448	.772
Specific density	1.599	.226
Total dissolved solids (mg/l)	.480	.750
Silica (SiO_4^-) (mg/l)	.933	.471
Phosphate (PO_4^-) (mg/l)	.238	.912
Sulphate (SO_4^-) (mg/l)	.166	.953
Nitrite (NO_2^-) (mg/l)	.056	.994
Nitrate (NO_3^-) (mg/l)	3.668	.028*
Ammonia (NH_3) (mg/l)	.473	.755
Chloride (mg/l)	.212	.928
Total hardness (CaCO_3/l)	.238	.912
Total alkalinity (CaCO_3/l)	.425	.788
Magnesium Hardness (mg/l)	.007	1.000
Calcium Hardness (mg/l)	.092	.984
Aluminum (Al) ($\mu\text{g}/\text{m}/\text{l}$)	.674	.620
Iron (Fe) ($\mu\text{g}/\text{m}/\text{l}$)	.003	1.000
Manganese (Mn) ($\mu\text{g}/\text{m}/\text{l}$)	.615	.658
Ozone(O_3) ($\mu\text{g}/\text{m}/\text{l}$)	1.000	.438
Cl ($\mu\text{g}/\text{m}/\text{l}$) radical	-----.	-----.

*Significant at the 0.05 level.

At significant level 0.05, Table 4 shows that there are differences among the mean of physiochemical characteristics of water data of sites only for two parameters pH and nitrate (NO_3^- mg/L), while there are no differences among the mean of water data analysis of sites for the other parameters under study. More specifically the results of multiple comparisons in Table 5 shows that there are slightly differences between the means of Sites 1 and 3 and Sites 2 and 5 as well as between Sites 3 and 5 for the parameter pH. In addition, there are differences between the means of Site 1 and all of Site 3, 4 and 5 as well as between Site 2 and 3 for the parameter nitrate (NO_3^- mg/L). These results of analysis are shown in Table 3 and Table 4. The multiple comparisons test was applied also to test the differences between the seasonal variation for each parameter and to evaluate the existence of the mean differences among the physiochemical characteristics of water data based on specific season.

Table 5: Multiple Comparisons Test for testing the differences between sites.

Parameter	(I) Sites	(J) Sites	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
pH	Site 1	Site 3	.071671	.024	-.33276	-.02724
	Site 2	Site 5	.071671	.041	.00724	.31276
	Site 3	Site 5	.071671	.007	.07224	.37776
Nitrate (NO_3^-) (mg/L)	Site 1	Site 3	.168184	.004	.21652	.93348
		Site 4	.168184	.032	.03902	.75598
		Site 5	.168184	.031	.04152	.75848
	Site 2	Site 3	.168184	.023	.06652	.78348

*Significant at the 0.05 level.

Table 6 shows at significant level 0.05, that there are differences among the mean of physiochemical characteristics of water data of seasons for the following parameters: temperature, electrical conductivity, specific density, sulphate (SO_4^- mg/l), nitrite (NO_2^- mg/l), ammonia (NH_3 mg/l), chloride (mg/l), total hardness (CaCO_3 mg/l), total alkalinity (CaCO_3 mg/l), magnesium hardness (mg/l), calcium hardness (mg/l) and manganese (Mn $\mu\text{g}/\text{l}$), while there are no differences among the mean of physiochemical characteristics of water data of season for the other parameters under study. In particular, the results of multiple comparisons show that there are differences between the means of Season (*i*) and Season (*j*), for each parameter described in Table 7 at significant level 0.05. These analysis of results is shown in Table 6 and Table 7.

Table 6: The One-Way ANOVA for the mean differences of data samples according to seasons for each parameter.

Parameter	F	Sig.
Temperature °C	47.796	.000*
pH	1.591	.231
Turbidity (NTU)	2.571	.090
Electrical conductivity ($\mu\text{S}/\text{cm}$)	11.889	.000*

Specific density	3.509	.040*
Total dissolved solids (mg/l)	1.927	.166
Silica (SiO ₄) (mg/l)	1.844	.180
Phosphate (PO ₄) (mg/l)	1.464	.262
Sulphate (SO ₄) (mg/l)	18.437	.000*
Nitrite (NO ₂) (mg/l)	38.415	.000*
Nitrate (NO ₃) (mg/l)	.938	.445
Ammonia (NH ₃) (mg/l)	3.437	.042*
Chloride (mg/l)	15.015	.000*
Total hardness (CaCO ₃ mg/l)	13.281	.000*
Total alkalinity (CaCO ₃ mg/l)	15.393	.000*
Magnesium Hardness (mg/l)	13.691	.000*
Calcium Hardness (mg/l)	4.313	.021*
Aluminum (Al) (µgm/l)	.829	.497
Iron (Fe) (µgm/l)	1.812	.185
Manganese (Mn) (µgm/l)	3.569	.038*
Ozone(O ₃) (µgm/l)	1.000	.418
Cl (µgm/l) radical	----.	----.

*Significant at the 0.05 level.

Table 7: Multiple Comparisons Test for testing the differences between seasons

Parameter	(I) Season	(J) Season	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Temperature oC	Winter	Spring	-5.120000*	.666108	.000	-6.53209	-3.70791
		Summer	-7.820000*	.666108	.000	-9.23209	-6.40791
		Autumn	-4.900000*	.666108	.000	-6.31209	-3.48791
	Spring	Summer	-2.700000*	.666108	.001	-4.11209	-1.28791
	Summer	Autumn	2.920000*	.666108	.000	1.50791	4.33209
Electrical conductivity (µS/cm)	Winter	Spring	1781.200000*	439.522821	.001	849.45324	2712.94676
	Spring	Summer	-1974.400000*	439.522821	.000	-2906.14676	-1042.65324
		Autumn	-2449.400000*	439.522821	.000	-3381.14676	-1517.65324
Specific density	Spring	Autumn	-.002400*	.000755	.006	-.00400	-.00080
Sulphate (SO ₄) (mg/l)	Winter	Summer	758.800000*	134.573586	.000	473.51674	1044.08326
		Autumn	595.400000*	134.573586	.000	310.11674	880.68326
	Spring	Summer	799.800000*	134.573586	.000	514.51674	1085.08326
		Autumn	636.400000*	134.573586	.000	351.11674	921.68326
Nitrite (NO ₂) (mg/l)	Winter	Spring	.012200*	.004921	.025	.00177	.02263
		Autumn	-.035200*	.004921	.000	-.04563	-.02477
	Spring	Autumn	-.047400*	.004921	.000	-.05783	-.03697
	Summer	Autumn	-.043200*	.004921	.000	-.05363	-.03277
Ammonia (NH ₃) (mg/l)	Winter	Summer	-.074000*	.027148	.015	-.13155	-.01645
	Spring	Summer	-.076000*	.027148	.013	-.13355	-.01845
	Summer	Autumn	.058000*	.027148	.048	.00045	.11555
Chloride (mg/L)	Winter	Summer	-17191.400000*	2851.075920	.000	-23235.41095	-11147.38905
	Spring	Summer	-14854.800000*	2851.075920	.000	-20898.81095	-8810.78905
	Summer	Autumn	14183.000000*	2851.075920	.000	8138.98905	20227.01095

Total hardness (CaCO ₃ /l)	Winter	Autumn	-7516.000000*	1670.928335	.000	-11058.20983	-3973.79017
	Spring	Autumn	-9670.600000*	1670.928335	.000	-13212.80983	-6128.39017
	Summer	Autumn	-8058.800000*	1670.928335	.000	-11601.00983	-4516.59017
Total alkalinity (CaCO ₃ /l)	Winter	Summer	-357.400000*	62.819742	.000	-490.57190	-224.22810
		Autumn	-284.800000*	62.819742	.000	-417.97190	-151.62810
	Spring	Summer	-305.600000*	62.819742	.000	-438.77190	-172.42810
		Autumn	-233.000000*	62.819742	.002	-366.17190	-99.82810
Magnesium Hardness (mg/l)	Winter	Spring	-2837.800000*	882.270548	.005	-4708.13001	-967.46999
		Summer	-4957.600000*	882.270548	.000	-6827.93001	-3087.26999
		Autumn	-4792.800000*	882.270548	.000	-6663.13001	-2922.46999
	Spring	Summer	-2119.800000*	882.270548	.029	-3990.13001	-249.46999
		Autumn	-1955.000000*	882.270548	.042	-3825.33001	-84.66999
Calcium Hardness (mg/l)	Winter	Summer	1576.200000*	531.986898	.009	448.43816	2703.96184
		Autumn	1723.000000*	531.986898	.005	595.23816	2850.76184
Manganese (Mn) (µgm/l)	Winter	Autumn	.003400*	.001428	.030	.00037	.00643
	Spring	Autumn	.004000*	.001428	.013	.00097	.00703

*Significant at the 0.05 level.

4. Conclusion

Based on the results of descriptive and multivariate statistics analysis in the Dumate al-Jandal water lake, observation assessed the linkages between spatio-temporal variability and water quality using. Not all sampled parameters indicated significant spatio-temporal variability. Multivariate analysis and ANOVA even its among seasonal variation or between sites construed that the lake water quality is primarily influenced by agricultural runoff and their original water resources. On the basis of molar concentrations most of the variations in water quality are explained by the natural soluble salts, nonpoint source nutrients, and environmental inorganic pollutants. The present study, concluded that the chemical parameters of water lake led to bad quality of water lake which resulted from the interaction of some environmental component. However, the

higher and lower changes among the physical properties, such as temperature, pH, EC, turbidities, specific density and total dissolved solids in addition to chemical characteristics like the concentration of nitrate, nitrite, ammonia, phosphate, sulphate total hardness, calcium hardness, and magnesium hardness were observed are not suitable for growth of aquatic organisms of the ecosystem services and activities. Based on the recorded observation and concentrations, the lake water quality is under strong natural pressure. Therefore, water resources management are recommended to solve such acute problems for sustainably use to hit the intended objective. This research emphasized that were observed in terms of molar concentration a highest in spring and lowest in autumn and winter at all the sites. But lower levels were observed at other sites among the seasonal variation; the lowest values were recorded in the winter at all the sites. The overall values of Multivariate Test Using Wilks' Statistics showed a significant difference of concentrations between sites for each parameter. On the basis of molar concentrations, among the anions which have a major concentration in lake and heavy metals in terms of their cations were found in a minor and moderate concentrations.

5. Conflict of Interests

The authors declare that there is no conflict of interests regarding part 1 of the publication of this paper.

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