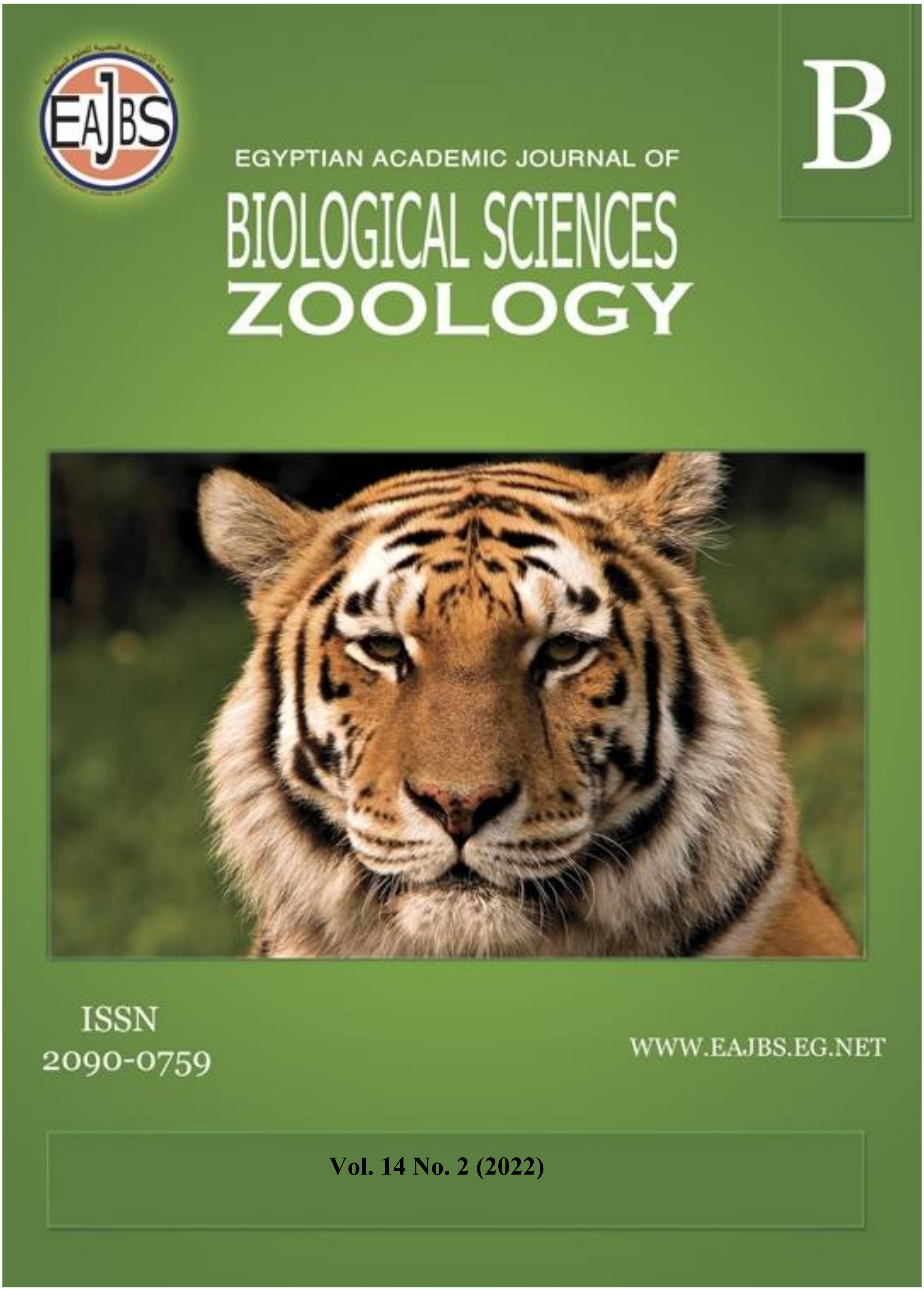

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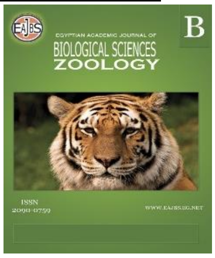

Effects of Physico-Chemical Parameters on The Efficiency of Stations and Water Lifting Pumps of Al-Salam Canal, Egypt

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ABSTRACT

In North Sinai, mixed water and reusing it would have a positive impact on the expansion of agricultural production, redistribution of the Egyptian population through resettlement, increase in employment and establishment of new rural communities. However, it may have some negative impacts on the waterways in relation to pollution of water that may have a serious effect on the operation and maintenance of the lifting pumps. In order to keep the project sustainable and protect the distribution system including the water lifting pumps, monitoring the quality of surface water in the main drains (Faraskur Drain, Sirw Drain and Bahr Hadous) and Al-Salam Canal was determined within 14 locations along Al-Salam network system during the summer season (2018). The present results indicated that it is difficult to make an overall assessment of the degree of contamination of the surface water along Al-Salam network system because there is considerable spatial variability between locations. Also, the present study showed locations that containing a high level of TSS, TDS, EC, BOD, COD, cations, anions, ammonia, heavy metals and oil and grease were displayed quite directly or indirectly corrosive to all the components of water lifting pump system.

INTRODUCTION

The Nile is the principal source of water for Egypt. It supplies Egypt with about 97% of the Egyptian needs. According to the 1959 agreement signed by Egypt and Sudan, Egypt has received about 55.5 milliard cubic meters/year. Other water resources have a small contribution and they are groundwater, rainfall and non-conventional water resources (Abdel Meguid, 2017).

Water demands are growing due to the economic growth of the Egyptian population; however available water supplies appear to be limited. The additional growth

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population affects the water demands by increasing human and livestock consumption and industrial activities as well as increasing the demand for food, irrigation and land reclamation schemes **(**Abdel Meguid, 2017 and Abdel Meguid**,** *et al*., 2018**)**.

In order to satisfy the demand of the growing generation, Egypt has engaged in intensive projects of economic development. One of those projects is North Sinai Development Project (NSDP). It is considered one of the most promising projects in terms of a comprehensive development process. It aims at reclamation of 400000 feddans by the use of 4.45 milliard cubic meter/year of mixed water through AL-Salam Canal. The water resources of the project are delivered from two distinct resources. The first source is agricultural drainage water through Lower Sirw Drain (0.435 milliard cubic meter/year) and Bahr Hadous Drain (1.905 milliard cubic meter/year). The second source is Nile water (2.11 milliard cubic meter/year) through Damietta Branch (Abdel Meguid, 2017).

This project has had a positive impact on expansion of the agricultural production, redistribution of the Egyptian population through resettlement, increasing employment in North Sinai and the establishment of new rural communities that include social and economic integration of various groups of population (MWRI, 2005).

However, there is serious concern about declining water quality in the waterways of the project. This concern is initially centered on the release of both point and non-point source pollutants within the drainage water such as heavy metals, sewage and other chemical wastes from industrial, agricultural and municipal origins. These materials separately or in combination may cause serious effects on the water quality and may induce harmful effects on both human health and the stream ecosystem. In addition, the establishment of modern high-yield agriculture (usually through artificial irrigation and drainage systems), alters generally stream hydrology upstream and downstream (DWAF, 1996; Haglund *et al*., 1996; Chin, 2000; Fishar, *et al.* 2006; Abdel-Baky, 2014; Abdel Meguid, *et al*., 2017).

Also, pollutants may have some negative impacts on the waterways in relation to pollution of water that may have a serious effect on the operation and maintenance of the water lifting pumps, particularly corrosion in terms of iron concentration and other parameters. In many cases, the chemical containments can be quite corrosive to all the components of the water-lifting pumps. (Zuo, 2007; Du Laing, *et al*., 2008; Sulaiman, *et al*., 2011; Cicek and Al-Numan, 2011; Geethanjall, *et al*., 2013; Yanyu, *et al*., 2019).

This study deals with the effect of different Physico-chemical parameters along Al-Salam Canal on the lifting pump operation in terms of their corrosion. Whereas, almost all of the studies conducted thus far have involved laboratory experiments under constant conditions and no work so far seems to have been carried out to ascertain whether the rate and course of corrosion are influenced by certain pollutants such as salinity, total dissolved salt, turbidity, alkalinity, cations, anions, nutrients, …etc) in water.

So, the ultimate goal in this present study is to monitor the ecosystem within the project area "field condition" to understand the real effects of these Physico-chemical parameters on the lifting pump operation, especially since it becomes a nationally essential prerequisites for an effective water resources management plan. This has an important economic return throughout the life of these stations and pumps.

MATERIALS AND METHODS

Study Area and Description:

Al-Salam Canal is to be fed from the Damietta Branch upstream of Farskour Dam with freshwater while supplemented with drainage water from the Lower Serw pumping station and Bahr Hadous drain near the outfall. The drain currently contains a collection of drainage water from all the catchments served, namely, Nizam, Beni-Ebeid, and Erad (Othman, *et al.,* 2012). The average yearly discharge of the Lower Serw pumping station is about 600 million m^3, and that of Bahr Hadous drain is about 2 billion m^3, bringing the total to 2.6 billion m^3/year. The average salinity measured at the Lower Serw pumping station is around 1,000 ppm, and that measured at Bahr Hadous outfall is about 1,400 ppm. The weighted average of both waters is 1,300 ppm. When this is mixed with fresh water at a ratio of 1:1 the salinity of the mixture is expected to be in the neighborhood of 800 ppm which is reasonable, given that the water is going to be used for the irrigation of sandy soils. It is planned to use 1.50 billion m^3/year of this quantity in the first and second phases of the project in addition to a similar quantity of fresh Nile water. The mixed water will be used to irrigate the reclamation lands in Port-Said Plateau, South Husseinia, and South Salhia, the total area of which is about 165,000 feddans in the first phase. The second phase covers the irrigation of 200,000 feddans extending along the northern coast of the Sinai Peninsula from Al-Arish westward (Othman, *et al*., 2012, Abdel Meguid, 2017).

Sampling Locations:

Fourteen locations were selected in Al–Salam network system Project. Table (1) and Figure (1) represent the diagram and characteristic features of locations of the study area at Al-Salam Project.

Table 1: Locations of the collected samples in Al-Salam network system**.**

Code	Locations	Description	km	coordinate
1	Damietta Branch at beginning of Al-Salam Canal	From The canal intake on the right bank of the canal	0.000 km	N° 31.7689509 E° 31.3952141
2	Al-Salam canal before mixing with Faraskur Drain	From the canal intake on the right bank of the canal	0.140 km	N° 31.7694800 E° 31.3940790
3	Suction of new Faraskur drainage station from El-Atawi Drain	From the canal intake before a distance 160 m from downstream El-Atawi Drain in Al-salam canal on the left bank	1.900 km	N° 31.7764051 E° 31.3797800
4	Al-Salam Canal after mixing with Faraskur Drain	From the canal intake at downstream El-Atawi Drain in Al-Salam Canal on the left bank	1.900 km	N° 31.7749581 E° 31.3789159
5	Suction of El-Sirw Drainage Station from the lower El-Sirw Drain	From the canal intake before a distance 970 m from downstream El-Serw Drain in Al-Salam Canal on the left bank	19.000 km	N° 31.8093829 E° 31.2480131
6	Discharge of El-Sirw drainage station	From the canal intake before a distance 860 m from downstream El-Serw Drain in Al-Salam Canal on the right bank	19.000 km	N° 31.8097420 E° 31.2487590
7	Al-Salam Canal after mixing with El-Sirw Drain	From the canal intake on the right bank of the canal	19.050 km	N° 31.8132339 E° 31.2562281
8	Al-Salam Canal before Al-Salam Station (1)	From the canal intake on the right bank of the canal	23.400 km	N° 31.8492150 E° 31.2344949
9	Al-Salam Canal after Al-Salam Station (1)	From the canal intake on the right bank of the canal	23.600 km	N° 31.8502980 E° 31.2343579
10	Al-Salam Canal before Al-Salam Station (2)	From the canal intake on the right bank of the canal	53.950 km	N° 32.0072618 E° 31.1069649
11	Suction of Al-Salam Drainage Station (3) from Bahr Hadous Drain	From the canal intake before a distance 300 m from downstream Bahr Hadous Drain in Al-Salam canal on the right bank	54.000 km	N° 32.0036690 E° 31.1051139
12	Al-Salam Canal after mixing with Al-Salam Drain (3)	From the Canal intake at downstream Bahr Hadous Drain in Al-Salam Canal on the right bank	55.500 km	N° 32.0074590 E° 31.0969920
13	Al-Salam Canal before mixing with Bahr Al-Bakar Drain	From the canal intake on the right bank of the canal	79.500 km	N° 32.2015611 E° 31.0165450
14	Al-Salam Canal after mixing with Bahr El- Bakar Drain	From the canal intake on the right bank of the canal	79.800 km	N° 32.2052411 E° 31.0166039

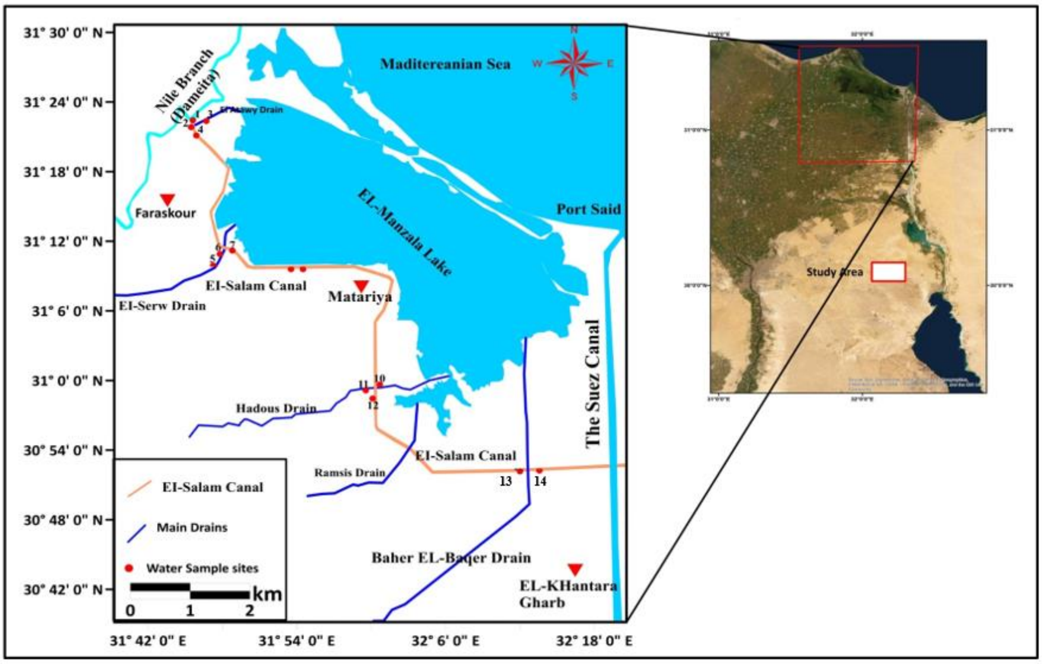

Fig. 1: Showing the Locations of The Collected Samples in Al-Salam Network System (Coordinate System)

Water Quality Sampling:

The surface water samples were collected during the summer "August" of the year "2018". The surface water sampling was carried out according to standard methods for the examination of water (APHA, 2005). Polyethylene containers of two-liter capacity were used for most chemical analyses. Four water samples were collected in each location to determine the average concentration for each parameter. All samples were stored in an ice cooler box and delivered immediately to the Central Laboratory for Environmental Quality Monitoring (CLEQM), National Water Research Center (NWRC), and the Ministry of Water Resources and Irrigation (MWRI).

The surface water was carried out, using the standard methods (APHA, 2005). Field parameters (temperature, pH, conductivity and dissolved oxygen) were measured in-situ using the multi-brobe system, model Hydrolab-surveyor. Heavy metals were determined by aspirating the samples in an inductively coupled plasma-optical emission spectrometer (ICP-OES) Perkin-Elmer optima 3000 coupled with an ultrasonic nebulizer.

Physico-chemical parameters which were measured in the present study were 32 parameters, as follows:

1	Temp.	9	Total suspended solid (TSS)	17	Nitrate (No_3)	25	Manganese (Mn)
2	Dissolved oxygen (DO)	10	Biological oxygen demand (BOD)	18	Nitrite (No_2)	26	Nickel (Ni)
3	PH	11	Chemical oxygen demand (COD)	19	Sulfate (SO_4)	27	Lead (Pb)
4	Carbonate (CO3)	12	Sodium (Na)	20	Ammonia (NH_3)	28	Chromium (Cr)
5	Bicarbonate (HCO_{3-})	13	Potassium (K)	21	Phosphate (PO_4)	29	Cadmium (Cd)
6	Total alkalinity (TA)	14	Calcium (Ca)	22	Aluminum (Al)	30	Arsenic (As)
7	Electrical conductivity (EC)	15	Magnesium (Mg)	23	Copper (Cu)	31	Zinc (Zn)
8	Total dissolved salts (TDS)	16	Chloride (Cl)	24	Iron (Fe)	32	Oil and grease (O & G)

All Physico-chemical parameters were compared to law 48/1982 for freshwater pollution protection during the summer and winter of 2018.

Statistical Analysis:

The correlation among Physico-chemical elements in the selected water surface locations during the summer season was statistically evaluated using Hierarchical Cluster Analysis (correlation is significant at the 0.05 level).

RESULTS AND DISCUSSION

The present study covered 14 sampling locations. Those were representing different ecological habitats of Al-Salam Canal network system. Different water quality parameters are measured in those sites during the summer of the year 2018 are shown in Table (2).

Table 2: Water quality parameters measured at Al-Salam network system during summer (August, 2018).

	Parameters	Unit	Locations													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**Temp.**	^{0}C	30	26	25	24	25	29	32	29	30	29	28	30	28	26
2	**Dissolved oxygen (DO)**	mg/l	5.22	5.54	3.46	4.52	2.23	4.55	5.48	6.33	6.12	5.87	2.33	4.42	4.52	5.66
3	**pH**		7.46	7.55	7.60	7.70	7.24	7.47	7.66	7.65	7.63	7.86	7.43	7.40	7.50	7.54
4	**Carbonate (CO3)**	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	**Bicarbonate (HCO_{3}.)**	mg/l	231.26	165.33	367.82	296.20	456.33	412.54	420.55	204.88	208.56	192.87	544.32	502.11	344.22	291.32
6	**Total alkalinity (TA)**	mg/l	231.26	165.33	367.82	296.20	456.33	412.54	420.55	204.88	208.56	192.87	544.32	502.11	344.22	291.32
7	**Electrical conductivity (EC)**	mmhos/cm	0.43	0.54	1.73	1.66	2.33	0.79	1.18	0.46	0.41	0.39	1.89	1.96	0.81	2.32
8	**Total dissolved salts (TDS)**	mg/l	269	367	1827	2112	1623	932	1412	402	367	344	2654	2143	1465	1201
9	**Total suspended solid (TSS)**	mg/l	43.15	46.25	277.2	270.66	174.75	52.25	149.96	37.35	56.45	21.15	192.25	176.75	47.15	202.7
10	**Biological oxygen demand (BOD)**	mg/l	18.12	19	78.26	67.56	156.12	135.43	96.02	33.43	30.5	22.12	271.44	208.12	51.43	38.65
11	**Biological oxygen demand (BOD)**	mg/l	59.51	47.75	122.23	109.54	132.52	98.72	166.07	43.54	46.25	18.25	234.22	317.32	112.65	105.09
12	**Sodium (Na)**	mg/l	119.56	82.44	276.32	402.25	116.42	98.76	442.18	61.45	87.72	51.66	228.34	155.44	115.23	392.66
13	**Potassium (K)**	mg/l	15.32	11.44	20.00	32.55	212.64	166.77	123.00	91.22	48.87	26.66	291.98	209.45	92.22	27.00
14	**Calcium (Ca)**	mg/l	23.12	20.10	50.32	38.44	199.00	120.40	101.12	80.50	82.30	67.98	215.77	191.00	98.20	45.50
15	**Magnesium (Mg)**	mg/l	35.32	31.25	47.66	72.51	22.96	27.61	71.45	23.42	35.86	18.25	63.55	71.44	32.12	45.26
16	**Chloride (Cl)**	mg/l	197.36	166.46	461.22	719.47	202.71	140.45	732.21	116.44	181.76	92.33	377.93	256.25	175.88	612.61
17	**Nitrate (No_{3})**	mg/l	0.5	0.4	0.6	0.4	1.2	1.8	0.06	0.8	0.4	0.5	2.2	0.8	0.6	0.8
18	**Nitrite (No_{2})**	mg/l	0.005	0.0014	0.043	0.029	0.024	0.053	0.025	0.017	0.008	0.0125	0.075	0.0212	0.009	0.012
19	**Sulfate (SO_{4})**	mg/l	176.81	139.15	391.76	561.15	288.97	301.06	396.43	162.55	177.34	91.98	489.46	333.81	187.11	163.18
20	**Ammonia (NH_{3})**	mg/l	0.20	0.2	0.7	0.8	4.7	1.1	0.6	0.31	0.04	0.051	3.2	1.2	0.4	0.081
21	**Phosphate (PO_{4})**	mg/l	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
22	**Aluminum (Al)**	mg/l	0.105	0.137	0.146	0.128	0.123	0.12	0.086	0.084	0.099	0.105	0.109	0.064	0.071	0.088
23	**Copper (Cu)**	mg/l	0.017	0.012	0,051	0,099	0,104	0.014	0.090	0.027	0.025	0.004	0.052	0.098	0.018	0.043
24	**Iron (Fe)**	mg/l	0.312	0.379	0.741	0.428	1.261	0.924	0.554	0.525	0.442	0.443	2.886	1.674	0.885	0.991
25	**Manganese (Mn)**	mg/l	0.065	0.068	0.214	0.158	0.187	0.124	0.161	0.094	0.072	0.096	0.791	0.541	0.135	0.161
26	**Nickel (Ni)**	mg/l	0.01	0.013	0.0074	0.027	0.061	0.0341	0.019	0.01	0.006	0.0049	0.0417	0.0305	0.026	0.019
27	**Lead (Pb)**	mg/l	0.0016	0.0022	0.005	0.0064	0.011	0.013	0.012	0.0084	0.003	0.007	0.01	0.011	0.012	0.011
28	**Chromium (Cr)**	mg/l	0.011	0.01	0.025	0.02	0.0591	0.04	0.046	0.0095	0.072	0.036	0.03	0.036	0.03	0.0125
29	**Cadmium (Cd)**	mg/l	0.001	0.002	0.0011	0.0006	0.003	0.0018	0.002	0.001	0.0007	0.001	0.0026	0.002	0.001	0.0008
30	**Arsenic (As)**	mg/l	0.0045	0.005	0.004	0.0031	0.0098	0.012	0.004	0.009	0.0068	0.0094	0.01	0.015	0.0091	0.0031
31	**Zinc (Zn)**	mg/l	0.032	0.013	0.091	0.069	0.152	0.041	0.126	0.025	0.021	0.330	0.198	0.182	0.065	0.199
32	**Oil and grease (O & G)**	mg/l	7.23	26.85	23.66	33.30	41.25	29.57	52.63	12.86	6.77	18.42	58.81	54.15	40.61	14.62

The water temperature ranged from 24 to 32 ^{0}C in summer (Table 2). The high-water temperature during summer may be due to a clear atmosphere and great solar radiation (Shama, *et al*., 2011 and Mohammed, 2015).

Concerning the dissolved oxygen, the present study showed that the value of dissolved oxygen ranged between 2.23 and 6.33 mg/l (Table 2). The variation in the values of dissolved oxygen might relate to the process of oxidation and reduction of organic and inorganic materials as well as it is a necessary element to all forms of life (Abdel Meguid, *et al*., 2018). Also, it is clear that the surface water in Al-Salam network system contained adequate dissolved oxygen, except for the locations of (3) "Faraskur Drain", (5) "El- Sirw Drain" and (11) "Bahr Hadous Drain". Where their values were lower than the Egyptian Standard Law of Environment 48/1982 (on the protection of human health "It is recommended in Articles 60 and 65 not be < 5 and <4 mg/l in Article 68"). This is an indication of the high levels of pollution that comes from the main drains which are probably contaminated Al-Salam system from agriculture and domestic inputs. Furthermore, the low content of the dissolved oxygen could be linked to moving water, and the aquatic plants' photosynthetic efficiency (Singh and Triweri 1979).

Concerning the pH, Boyd (1979) stated that pH is a measure of hydrogen ion concentration in water. It may be either in basic form or acidic form. In the present study, the water quality data indicated that the pH value was alkaline. It ranged from 7.24 to 7.86 in summer (Table 2). It is clear from the present study that, an increase in photosynthetic activity of algal population results in an increased pH value which is conceded with the result of Deyab (1987). Similarly, Gabr and El-Zahar (2018) showed the annual average of pH was that all water samples' mean value is 7.78 in (the values ranged from 7.38 to 8.13). Also, it is similar to the finding of Elkorashey (2012) who mentioned that the pH values in Al-Salam Canal range between 7.35and 8.20 which fall within the permissible limits according to the Egyptian Standard Law of Environment 48/1982.

The present result showed also that the concentrations of carbonate were zero in all different locations during summer (Table 2). It means that the surface water in Al-salam network system tends to be alkaline.

Concerning the bicarbonate (HCO_3-) and total alkalinity (TA), the present study showed a clear indication that the media of water is alkaline in Al-Salam network system. The trend of total alkalinity is exactly similar to that of HCO_3. Generally, the HCO_3 values and PH values have a direct relationship (Abdel Aziz, 2014) and photosynthesis as well as the respiration process play an important role in releasing carbon dioxide consequently increasing or decreasing the bicarbonate (Abdel Aziz, 2014). Also, the variation in the concentration of (TA) depends upon the type of discharged wastes (Abdel-Baky, 2001). The values of bicarbonates and total alkalinity are shown in Table (2). The concentrations ranged between 165.33 and 544.32 mg/l in summer, where, the location of (2) "Al-Salam canal before mixing with Faraskur Drain" represented the lowest value while the location of (11) "Suction of Al-Salam Drainage Station (3) from Bahr Hadous Drain" represented the highest value. The highest value might be attributed to the untreated domestic wastewater from Bahr Hadous drain. A similar result was obtained by El Korashey (2012) who measured the value of (TA) in Al-Salam Canal.

The present study showed variation in the concentration of electric conductivity (EC) along Al-Salam network system. These variations might be due to agricultural drainage water from relatively saline soil received by drains. A similar result was obtained by (Haglund *et al*., 1996). The (EC) ranged from 0.39 to 2.33 mmhos/cm in summer with a minimum value at the location of (10) "Al-Salam Canal before Al-Salam Station (2)" and a maximum value at the location of (5) " Suction of El-Sirw drainage Station from the lower El-Sirw Drain " (Table 2). It is clear that the conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (negative ions) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge) as well as other organic compounds like oil.

The present study showed variation in the concentration of total dissolved salts (TDS) along Al-Salam network system (Table 2). The concentration of (TDS) ranged between 269 and 2654 mg/l, where the minimum value was detected at the location of (1) "Damietta Branch" and the maximum value was detected at the location of (11) "Suction of Al-Salam drainage Staion (3) from Bahr Hadous Drain". The increase in value of (TDS) might be attributed to inorganic salts that dissolve in water originating from sewage, urban, and agricultural runoff as well as industrial wastewater.

Concerning the total suspended solid (TSS), it ranged between 21.15 and 277.2 mg/l in summer (Table 2), where the minimum value was recorded at the locations of (10) "Al-Salam Canal before Al-Salam Station (2)", while the maximum value was recorded at the location of (3) "Suction of new Faraskour Drainage from El-Atawi Drain".

The present study showed that the concentration of biological oxygen demand (BOD) ranged between 18.12 and 271.44 mg/l in summer with a minimum value at the location of (1) "Damiatta Branch before the beginning of El-Salam Canal" and maximum value at the location of (11) "Suction of El Salam Drainage Station (3) from Bahr Hadous Drain" (Table 2). This might be attributed to the significant amounts of organic pollutants from domestic diffuse sources and fertilizers from Bahr Hadous Drain itself.

Concerning, the chemical oxygen demand (COD), the present result showed that the values of (COD) were high in Al-Salam network system, especially in the drains (Table 2) which indicated that the amount of pollution in the test samples was high. The value of (COD) ranged between 18.25 and 317.32 mg/l in summer with a minimum value at the location of (10) "El-Salam Canal before El-Salam Station (2)" and a maximum value at the location of (12) "El-Salam Canal after mixing with El-Salam Drain (3)". Moreover, the present study showed that the concentrations of (COD) exceeded the limits of Law 48/1982 (10 and < 15 mg/l).

The present study showed that the concentration of sodium ranged between 51.66 and 442.18 mg/l in summer, with a minimum value at the location of (10) "El-Salam Canal before El-Salam Station (2)" and maximum value at the location of (7) "Al-Salam Canal after mixing with El-Sirw Drain" (Table 2).

In addition, the concentration of potassium ranged between 11.44 and 291.98 mg/l in summer, with a minimum value at the location of (2) "Al-Salam canal before mixing with Faraskur Drain" and a maximum value at the location of (11) "Suction of Al-Salam Drainage Station (3) from Bahr Hadous Drain" (Table 2).

Furthermore, the concentration of calcium ranged between 20.10 and 215.77 mg/l in summer, with a minimum value at the location of (2) "Al-Salam canal before mixing with Faraskur Drain" and maximum value at the location of (11) "Suction of Al-Salam Drainage Station (3) from Bahr Hadous Drain" (Table 2).

The present study showed that the concentrations of magnesium were low values when compared with calcium concentrations because there is a preponderance of Ca over Mg in sedimentary rocks, (Abdel-Halim, 1993). The concentration of magnesium ranged between 18.25 and 72.51 mg/l in summer, with a minimum value at the location of (10) "Al-Salam Canal before Al-Salam Station (2)" and maximum value at the location of (4) "Al-Salam Canal after mixing with Faraskur Drain" (Table 2).

The present study showed that the concentration of chloride ranged between 92.33 and 732.21 mg/l in summer, with a minimum value at the location of (10) "Al-Salam Canal before Al-Salam Station (2)" and maximum value at the location of (7) "Al-Salam Canal after mixing with El-Sirw Drain" as shown in table (2). It is clear that the increase in the chloride in some locations might be connected to passing the underground water At El-Manzala Lake region to Al-Salam network system and/or to the disposal of Bahr Hadous Drain water which might reach to Al-Salam Canal (Al Attar, 2000).

The present study showed that the concentration of nitrate ranged between 0.06 and 2.2 mg/l in summer, with a minimum value at the locations of (2), (4), (7) and (9) and a maximum value at the location of (11) as shown in Table (2). The increase of its value at the location of (11) might be due to the decomposition of dead algae where complex proteins are converted by bacteria to nitrogenous organic matter and finally into nitrate or because of the presence of biodegradable organic pollutants and the oxidation of ammonia by nitrifying bacteria. This result coincides with the results of (Ali, 2008; Yousry, 2009 and Abdel-Baky, 2014).

The present study showed that the concentration of nitrite ranged between 0.004 and 0.075 mg/l in summer, with a minimum value at the location of (2) and a maximum value at the location of (11) as shown in Table (2).

The present study showed that the concentration of sulfate ranged between 91.98 and 561.15 mg/l in summer, with a minimum value at the location of (10) and maximum value at the location of (4) as shown in Table (2). The relative increase in sulfate concentrations might be due to the death and decomposition of aquatic microorganisms and then oxidation of the liberated sulfur into sulfate in the presence of high dissolved oxygen, or might be due to the sulfate accumulation by phytoplankton. These results are coincident with those reported by (El-Hadad, 2005; Abdo *et al*. 2010; Abdel-Baky, 2014). In addition, it is clear that the sulfate concentrations in the surface water at locations of (3, 4, 5, 6, 7, 11 and 12), where they were exceeding the limit (< 200 mg/l) according to Article 60 of Law 48/1982.

The present study showed that the concentration of ammonia ranged between 0.04 and 4.76 mg/l in summer, with a minimum value at the location of (9) and a maximum value at the location of (5) as shown in table (2). However, the concentrations of ammonia in all sites do not exceed the allowed limits of Law 48/1982 (< 0.5 mg/l).

In the present study, the analysis of phosphate showed that all locations during summer had < 0.2 mg/l as shown in Table (2). This value is not exceeding the permissible limits for Law 48/1982.

Concerning the heavy metals (Table 2), the present study showed that the concentration of aluminum ranged between 0.064 and 0.146 mg/l, with a minimum value at the location of (12) and a maximum value at the location of (3). The concentration of copper ranged between 0.004 and 0.104 mg/l, with a minimum value at the location of (10) and a maximum value at the location of (5). In addition, the present result showed that values copper at different locations did not exceed the maximum permissible limit (1.5 mg/l). The concentration of iron ranged between 0.312 and 2.886 mg/l, with a minimum value at the location of (1) and a maximum value at the location of (11). The extreme increase in the value of iron at the location of (11) might be attributed to the increased mobilization of iron from sediment to water or the discharge of pollutants that were contaminated with iron from Bahr Hadous Drain. In addition, the present result showed that values of iron at all different locations did not exceed the maximum permissible limit (1.5 mg/l). The concentration of manganese ranged between 0.065 and 0.791 mg/l, with a minimum value at the location of (1) and a maximum value at the location of (11). The extreme increase in the value of manganese at the location of (11) might be attributed to the increased mobilization of manganese from sediment to water or the discharge of pollutants that were contaminated with manganese from Bahr Hadous Drain. However, the lowest manganese concentration recorded at location (1) might be attributed to the uptake by phytoplankton leaving the water poor from these trace metals (Masoud, *et al.*, 2005). In addition, the present result showed that the values of manganese at different locations did not exceed the maximum permissible limit (1 mg/l). Finally, the concentration of zinc ranged between 0.013 and 0.330 mg/l, with a minimum value at the location of (2) and a maximum value at the location of (10). In addition, the present result showed that the values of zinc at all different locations did not exceed the maximum permissible limit (5 mg/l).

Concerning the rare trace elements (Table 2), the present study showed that the concentration of nickel ranged between 0.0049 and 0.061 mg/l, with a minimum value at the location of (10) and a maximum value at the location of (5). The concentration of lead ranged between 0.0016 and 0.013 mg/l, with a minimum value at the location of (1) and a maximum value at the location of (6). The concentration of chromium ranged between 0.0095 and 0.072 mg/l, with a minimum value at the location of (8) and a maximum value at the location of (9). The concentration of cadmium ranged between 0.0006 and 0.003 mg/l, with a minimum value at the location of (4) and a maximum value at the location of (5). Finally, the concentration of arsenic ranged between 0.0031 and 0.015 mg/l, with a minimum value at the location of (4) and (14) maximum value at the location of (12).

Concerning the oil and grease (O&G), the present study showed that the concentration of (O&G) ranged between 6.77 and 58.81 mg/l in summer, with a minimum value at the location of (9) and maximum value at the location of (11) as shown in table (2). According to Law 48 of 1982 (Article 60 of the Regulations), the value of oil and grease along at location of (1) was exceeding the limit (0.1 mg/l). Also, the values of oil and grease exceeded the maximum permissible limit (15 mg/l) at all locations except locations (1), (9) and (14) in summer. Such contamination in freshwater has serious impacts on the environment and living organisms. These negative effects are due to the discharge of various organic compounds that make up crude oil and oil distillate products, the majority of which include various individual hydrocarbons (Manoli, *et al.,* 2000; McGenity, *et al.,* 2012 and EPA, 2013).

From the previous result (Table 2), it is clear that it is difficult to make an overall assessment of the degree of contamination of the surface water along Al-Salam network system because there is considerable spatial variability between locations. This spatial variability is due to different proximities to contaminant sources such as point and non-point sources of pollutants. This result coincides with the results of Abdel Meguid and Abdel Rasheed (2011 and 2012) and Abdel Meguid, *et al*. (2013). Also, its resemblances to the results of Allen (1996) and Kominkova and Nabelkova (2007) who mentioned that pollutants entering the aquatic environment and their behavior and eco-toxicological effect are not well understood especially if they occur in waterways that have different environmental conditions which highly dependent on the size of the waterway and its order, waterway morphology and its locality, and many of other factors including urban drainage emission.

To understand of relationships between pollutants and the environment as well as the lifting water pumps, correlations among Physico-chemical elements in the selected water surface locations during the summer season were statistically evaluated by using Hierarchical Cluster Analysis.

Hierarchical Cluster Analysis dendrogram of pH, carbonate, bicarbonate and total alkalinity during the summer season showed that it could be clustered into two main groups as shown in Figure (2). The first group that contained the highest values was represented by the locations of (12), (11), (5), (7) and (6), respectively. While, the second group which resemblances to the Nile water (1) that contained the lowest values was represented by the locations of (8), (9), (10), (1), (2), (4), (14), (3) and (13), respectively. The main concern about alkalinity is its very low and very high values that can cause nuisance problems and make the water corrosive which leads to potentially harmful metals dissolving from the pipes and water lifting pumps, as well as increasing the solubility of the metals in water. Fortunately, the present study showed that the surface water at all different locations along the Al-Salam network system tended to be more alkaline. This type of water can reduce the corrosive effect on concrete. Moreover, Bosnic, *et al*., (2000) reported that metals tend to remain insoluble and more inert, and hydrogen sulfide evolution is minimized within the more alkaline water. So, it is clear that the discharged water is preferable and useful during the operation of the water lifting pumps in order to prevent corrosion.

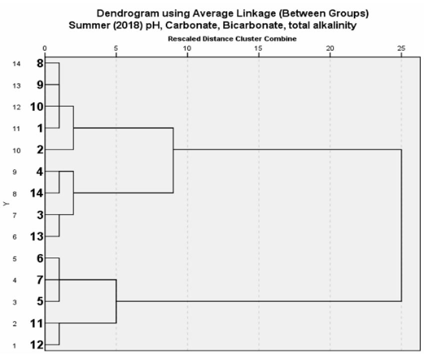

Fig. 2: Hierarchical Cluster Analysis Dendrogram of pH, carbonate, bicarbonate and total alkalinity at different locations of Al-Salam network system during summer (2018).

Concerning both (EC) and (TDS) in the summer, the results of cluster analyses to test similarities and variations among sites showed that the cluster contained two main groups. The first group that contained the highest salinity was represented by the location of (11), followed by the locations of (3), (12) and (4) and then the locations of (14), (6), (5), (13) and (7), respectively as shown in Figure (3). While, the second group which contained the lowest value was represented by the locations of (2), (9), (10), (8) and (1), respectively. In the present study, both (EC) and (TDS) can get from different sources such as agricultural and urban runoff, industrial wastewater, sewage and natural sources such as leaves, silt, plankton, and rocks. High levels of (EC) and (TDS) can lead to nuisance problems such as scale buildup in pipes and reduced efficiency of water lifting pump operation. In addition, Hatje *et al*., (2003) and Du Laing, *et al*., (2008) have demonstrated an increase in some metal mobilisation with increasing salinities. Seawater is a highly corrosive electrolyte to all kinds of metals. However, an increase in salinity could contribute to lower uptake levels of pollution from the sediments Kenison, (2015).

Minerals dissolved in water separate into charged particles (ions) that conduct electricity. Conductivity is a problem only when the water has high mineral content. In general, the NaCl solutions accelerate the cathode stripping process of the nearby coating, thereby accelerating the corrosion rate of the metal (Fang, 2006 and Yanyu, *et al*., 2019). Based on these statements and the present result, it is clear that the salinity within Al-Salam network system is low which means it will not scale buildup in the pipe, but it will have a fundamental role in the corrosive process in combination with other factors that provide corrosive environment.

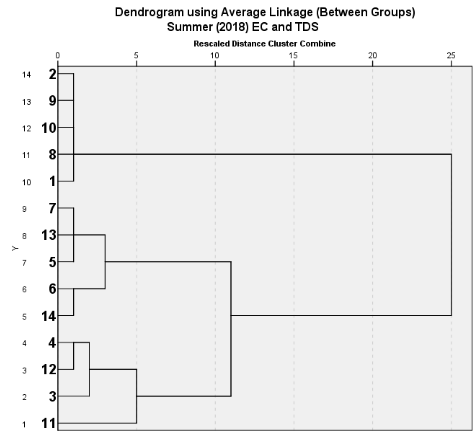

Fig. 3: Hierarchical Cluster Analysis Dendrogram of EC and TDS at different locations of Al-Salam network system during summer (2018).

Concerning (TSS), the cluster analysis divided the gained result into two groups. The first group that contained the highest (TSS) value was represented by the location of (7), followed by the locations of (14), (11), (12) and (5) and then the locations of (4) and (3), respectively as shown in Figure (4). In the case of the lowest value, the second group contained the locations of (2), (13), (1), (8), (6), (9) and (10), respectively (Fig. 4). The major problem can develop if these materials settle in the pipework as they lead to blockages. This problem can be very serious when blockages occur in inaccessible pipe work. The cost of replacing a burned-out motor or broken rotors is high. Moreover, (TSS) may cause major wear to the pump assembly by acting as an abrasive that slowly damages the pump's bearings and other components. In addition, dirt, hard water minerals, small stones, or other debris can reduce water flow or cause the pump to stop working completely. From the present study, it is clear that the observed high value of (TSS) at the locations of (7), (14), (11), (12) and (5) (Fig. 4) might have an accelerating effect on corrosion attack.

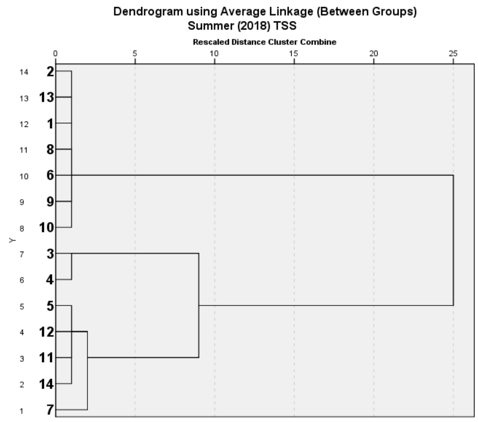

Fig. 4: Hierarchical Cluster Analysis Dendrogram of TSS at different locations of Al-Salam network system during summer (2018).

Concerning both (BOD) and (COD) in the summer, the cluster analysis divided the gained result into two groups. The first group, which contained the highest value was represented at the locations of (12) and (11), respectively (Fig. 5). In the case of the lowest value, the second group contained the locations of (8), (9), (1), (2), and (10), followed by the locations of (5) and (6) and then the location of (7), respectively (Fig. 5). In case of (BOD) and (COD), many components in effluents are broken down by bacterial action into more simple components. Oxygen is required for both the survival of these bacteria (aerobic bacteria) and the breakdown of the components. Depending on their composition, this breakdown can be quite rapid or may take a very long time. Under normal working conditions, both water and carbon dioxide are produced in large volumes; the process, however, depends upon bacterial growth. As the bacteria die, they form sludge or waste water components which can be carried greater distances before breaking down. This sludge may contribute to corrosion in the operating system of water-lifting pumps. This concedes with a result of (Sulaiman, *et al*., 2011)) who reported that all the parameters such as total dissolved solids (TDS), chemical oxygen demand (COD), total organic carbon (TOC), turbidity, nitrite, iron, lead and pH contributed to the corrosion in the open circulating cooling systems. So, this sludge has high water content and is often quite difficult to dewater, thus adding considerably to the operation system, maintenance and treatment costs, especially at locations (12) and (11) which contain the highest (BOD) and (COD) values during summer season (Fig. 5).

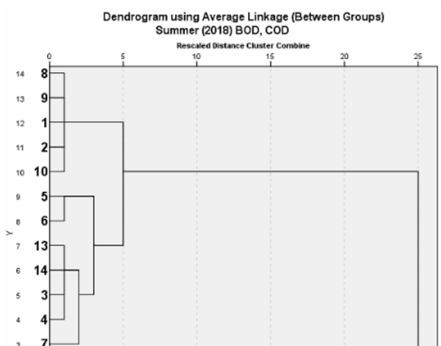

Fig. 5: Hierarchical Cluster Analysis Dendrogram of BOD and COD at different locations of Al-Salam network system during summer (2018).

Concerning the total cations and anions, in summer, the cluster analysis divided the gained result into two groups. The first group that contained the highest value was represented at the location of (3), followed by the location of (7), and then the locations of (14) and (4), respectively (Fig. 6). In the case of the lowest value, the second group was the locations of (1), (2), (9), (13), (8) and (10), followed by the locations of (5), (12) and (6) and then the location of (11), respectively (Fig. 6).

In order to get a clear picture of the anions and cations, cluster analysis was done for each of them during the summer season. Concerning the cations, the cluster analysis showed that there were two groups. The first one contained the locations (4, 14, 7 and 3) having the lowest values of cations. While, the second group, which contains the highest value was divided into many subgroups. The location of (11) contained the highest value, while the location of (1) contained the lowest value in this sub-group (Fig. 7). Concerning the anions, the cluster analysis showed that there were two groups. Each of them was divided into many subgroups. The highest value was at the location of (14) and the lowest one was detected at the location of (9) as shown in Figure (8). It is clear that the major corrosion parameters are listed as dissolved salts, oxidizing agents, temperature and pH. Salts are minerals that dissolve in water. They include potassium, chloride, sodium, sulfate, magnesium, and calcium. These are present in higher concentrations in seawater than in freshwater (Cicek and & Al-Numan, 2011). Concerning, the cations, they are the highly favorable condition for corrosion attack (Geethanjall, 2013). Corrosion pits were observed in solutions with soft metal cations such as Na+ and K+. The corrosion potential increases with increasing metal cation hardness (Otani, *et al*., 2014). The cations may form hard water when they are found in high concentrations, specifically calcium and magnesium. Hardness does not pose health but it can be a nuisance because it a build-up of scale on pipes and fixtures that can lead to lower water pressure and shorten the life of water lifting pump systems or it may leave a sticky film of soap on the body which provides a good habitat for growth and accumulation of some kind microorganisms that may enhance the corrosive process. So, it is clear from the present study that the observed high concentrations of cations at the locations of (11), (6), (12) and (5) in summer (Fig. 7) might have an accelerating effect on corrosion attack. Concerning the anions, all electrochemical results lead to the same conclusion that the corrosion rate on steel is markedly affected by the identity of the anion. This aggressively order is sulfate > chloride > bromide > per chlorate > iodide > nitrate (Brett and Melo, 1997). In general, sulfate (So_4^{--}) and chloride (Cl^-) are one of the parameters that affect aqueous corrosion attack on metals including corrosion resistance alloys (Cicek and & Al-Numan, 2011). With increasing the concentrations of anions, especially the chloride the corrosion attack increases (Ismail, *et al*., 2013) and destroy the rust materials (Yanyu, *et al*., 2019). As a result, it weakens girders, pipe works, pumps and building supports (Bosnic, *et al*., 2000).

Furthermore, sulfate-reducing bacteria (SRB) and sulfur-oxidizing bacteria, secrete organic acids and produce extracellular polymeric substances that have corrosive effeminacy on some metals such as steel and iron (Hamilton, 2003 and Zuo, 2007). This type of corrosion occurs most frequently when stagnant water remains in the pump when shut down for an extended period of time. Based on these statements, it is clear from the present study that the observed high concentrations of anions at the locations of (14), (7), (4), (11) and (3) in summer (Fig. 8) might have accelerating effect for corrosion attack.

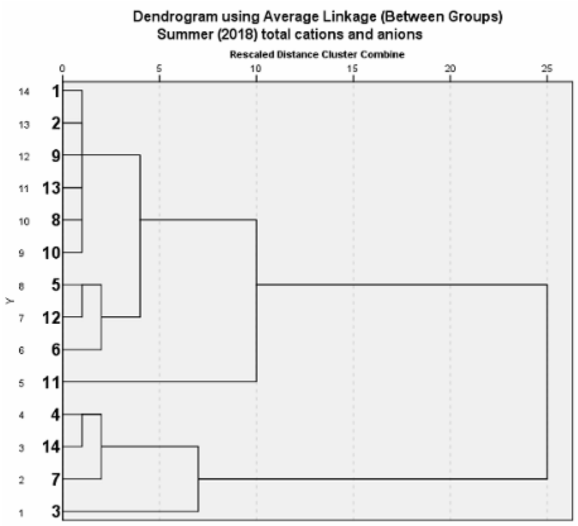

Fig. 6: Hierarchical Cluster Analysis Dendrogram of total cations and anions at different locations of Al-Salam network system during summer (2018**).**

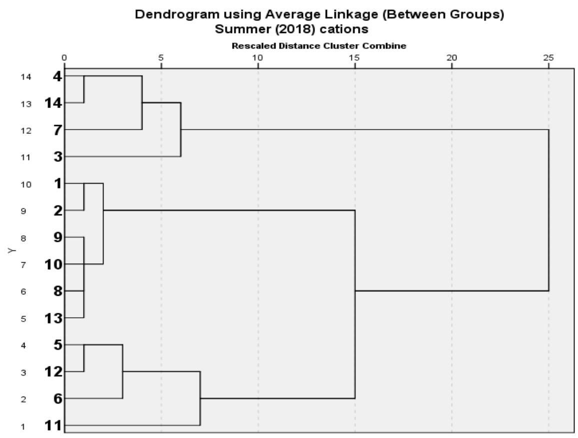

Fig. 7: Hierarchical Cluster Analysis Dendrogram of cations at different locations of Al-Salam network system during summer (2018).

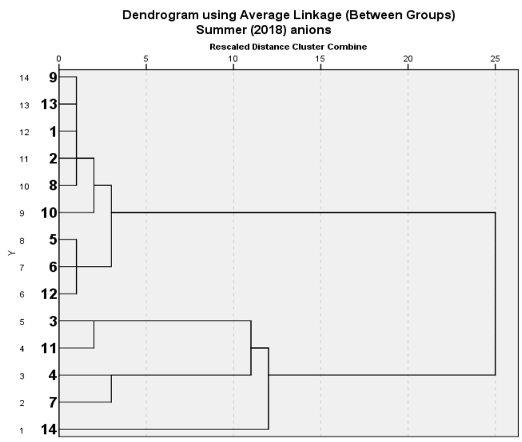

Fig. 8: Hierarchical Cluster Analysis Dendrogram of anions at different locations of Al-Salam network system during summer (2018).

Concerning the ammonia in the summer, the gained result of cluster analysis divided the whole set into two groups. The first group, that containing the highest value was represented at the location of (11) and (5), respectively (Fig. 9). In the case of the lowest value, the second group was divided into two subgroups, the first one contained the lowest value at locations of (1), (2), (9), (10), (14), (8) and (13), respectively (Fig. 9). The other subgroup, that containing mild high concentrations was the locations of (4), (7), (3), (12) and (6), respectively, as shown in Figure (9). Ammonia has also a direct corrosive effect in aqueous solutions (Uhlig, 1984). Also, it may have an indirect effect as a nutrient for blooming some kinds of microorganisms such as green and blue-green algae as well as microbial organisms which may have corrosion attack. Based on that, the cluster analysis showed that the most susceptible locations to the direct or indirect effect of corrosion attack induced by ammonia are the locations of (11) and (5) as shown in Figure (9).

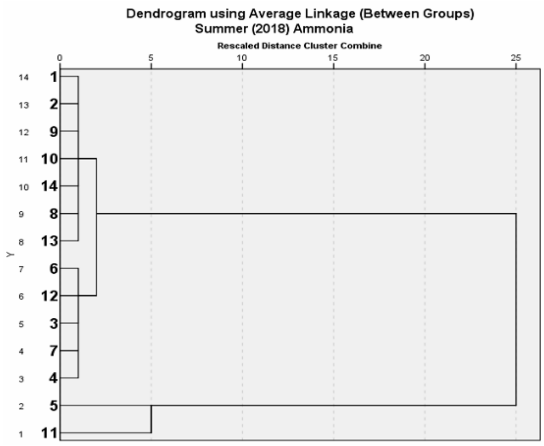

Fig. 9: Hierarchical Cluster Analysis Dendrogram of ammonia at different locations of Al-Salam network system during summer (2018).

Concerning the total heavy metals in aquatic systems, corrosion occurs when an electric current flows from one part of the metal (anode) through the water (electrolyte) to another part of the metal (cathode). Corrosion takes place at the anode only. The cathode is the driving force of the corrosion action. Similarly, galvanic corrosion occurs when two different metals are coupled together. The metal with the least resistance becomes the anode and will corrode due to the electrochemical reaction produced. For simple understanding, water acts as a solvent (cathode) and when it contains any predictable concentration of metals, corrosion will occur on any equipment containing the same metals in the presence of current flow. The present study showed that the common heavy metals which persisted in the water of Al-Salam network system in high concentrations were aluminum, copper, iron, manganese and zinc. In summer, the cluster analysis showed that the concentration of total heavy metals was divided into two groups. The first group, which contains the highest value was represented at the location of (3) and followed by the locations of (5) and (4), respectively. In the case of the lowest value, all the remaining locations were in the same order in the second group (Fig.10). Based on this previous result, the cluster analysis showed that the most susceptible locations to direct or indirect effect of corrosion attack induced by heavy metals are the locations of (3), (5) and (4).

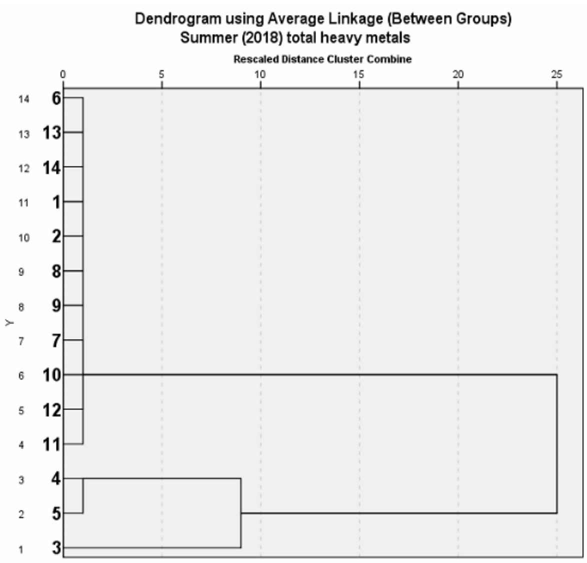

Fig. 10: Hierarchical Cluster Analysis Dendrogram of the total of heavy metals at different locations of Al-Salam network system during summer (2018).

Concerning the oil and grease, the cluster analysis in the present study divided the gained result into two main groups. The first group, which contains the highest value was represented at the locations of (11), (12) and (7), respectively (Fig. 11). In the case of the lowest value, the second group was divided into two subgroups. The first one contained the lowest value at the locations of (1), (9), (8), (14) and (10), respectively (Fig. 11). The second subgroup contained a mild value at the locations of (5) and (13), followed by the locations of (2), (6), (3) and then the location of (4). Floating grease and fatty particles agglomerate to form 'mats' which then bind other materials such as algae and aquatic weeds, thus causing a potential blockage problem, especially during the water lifting pump operation. If the surface waters are contaminated with grease or thin layers of oil, oxygen transfer from the atmosphere is reduced. If these fatty substances emulate, they create a very high oxygen demand on account of their bio-degradability (Bosnic, *et al*., 2000). Based on these previous results, the cluster analysis showed that the most susceptible locations to the direct or indirect effect of corrosion attack induced by oil and grease are the locations of (11), (12) and (7) as shown in Figure (11).

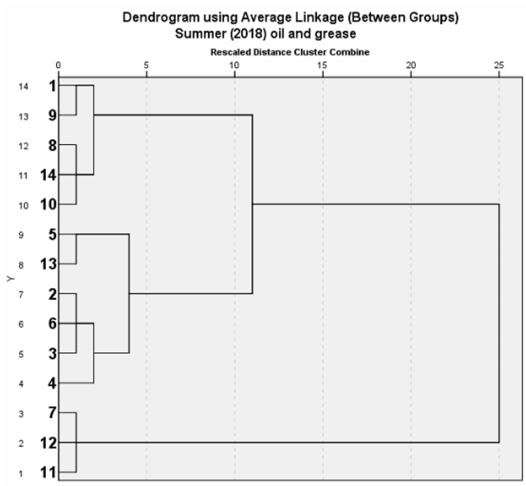

Fig. 11: Hierarchical Cluster Analysis Dendrogram of oil and grease at different locations of Al-Salam network system during summer (2018).

Conclusions

Physico-chemical characteristics of water samples in Al-Salam network system during the summer season (2018) have been presented. The present results indicated that it is difficult to make an overall assessment of the degree of contamination because there is considerable spatial variability between locations due to different proximities to contaminant sources such as point and non-point sources of pollutants. Depending on the chemical makeup of water, the water itself might be quite directly or indirectly corrosive to all the components of the water-lifting pump system. Corrosion is one of the most common problems affecting water transport.

Recommendations

1. Implement effective strategies for the treatment of the drainage water resources before mixing with the Nile water.
2. For excellent ability in reducing the corrosion on the surfaces of water lifting pump system, effective corrosion control requires the following:
- Frequency of maintenance and inspections of the operating system, selection of the anticorrosive metals and alloys and adding maintenance dosages of chemical corrosion inhibitors.
- Regular removal of any accumulated material from the fences.
3. Further study should be done on microbial activity and its responsibility for corrosion attacks.

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