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Water Quality Assessment of the northern part of Suez Gulf (Red Sea, Egypt), using Principal Component Analysis.

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ABSTRACT

Suez bay is a large harbor in the northern part of Suez gulf at the south entrance of the Suez Canal, It is subjected to different sources of pollution. The present study was achieved to assess the physicochemical parameters, nutrient salts and Water Quality Index (WQI) in the Suez Bay. The annual mean range of water temperature, pH, salinity, dissolved oxygen, oxidizable organic matter, biological oxygen demand, total suspended solids, ammonia, nitrite, nitrate, and dissolved inorganic phosphate and silicate was;23.69-25.11°C, 7.97-8.11, 40.89-41.55‰, 6.92-9.09 mgO_2L^{-1}, 7.57-9.60 mgL^{-1}, 3.00-4.00mgO_2L^{-1}, 17.75-27 mg L^{-1}, 4.35-9.28 $\mu molL^{-1}$, 1.56-4.14 $\mu molL^{-1}$, 5.15-12.99 $\mu molL^{-1}$; 1.26-2.43$\mu molL^{-1}$and 4.65-8.00 $\mu molL^{-1}$, respectively. The N:P ratio fluctuated between 2.95 and 39.17 with main value of 16.14 indicating that the different sites in the northern part of the Suez Gulf are, either, N limited or P limited or N/P co-limited. Based on the Principal Component Analysis Data, the hot spots (the sites are more polluted) include Al-Adabyia, Al-Adabyia Effluent, Textile Egypt Eran Company and Attaka Power Station, respectively.

INTRODUCTION

Marine coastal area is of a major serious concern due to its threatening from over exploitation and pollution caused by human activities that can affect aquatic ecosystems inhabitating the area including marine life that in turn affects human health. The Northern Red Sea is an important sea area for fishing and spectacular marine environment (**Dorgham *et al.* 2012**). The Gulf of Suez can be regionally divided into two regions, the north part of the Gulf, Known as Suez Bay and the rest area of the Gulf that is the south part. The Suez Bay is located between longitude 32° 28\ and 32° 34\E and latitude 29° 54\ and 29° 75\ N. The Bay is a shallow extension of the Gulf of Suez, roughly twisted in shape, with its major axis in the NE-SW direction. The average length along the major axis is 13.2 km; its average width along the minor axis is 8.8 km, the mean depth is 10 m and its horizontal surface area is 77.13 Km^2 (**Hamed *et al.* 2010**). The bay is connected to the Suez Canal by a dredged channel of 12 m depth through the north eastern side of the bay (**Meshal, 1967**). The northern part of the bay is occupied by the city of Suez. There are two sources for Suez Bay water: The Suez Canal and Gulf of Suez waters. The circulation in the Suez Bay can be followed by following the proper characteristics of the two water types.

Meshal (1967) found that seawater of the Gulf of Suez enters the bay on the eastern side (Sinai side) and leaves on the western side. The seawater from Suez Canal is deflected to the western coast. Therefore, there is a persistent anticlockwise circulation in the bay.

As Suez bay is the south entrance of the Suez Canal, it is considered as a large harbour. More than 100 ships and tankers are waiting daily for crossing the canal to the Mediterranean. This bay is subjected to different sources of pollution: Sewage and garbage from the city of Suez (El kabanoon) and from ships awaiting transit through the Suez Canal; ship-based sources including operational spills from vessels loading or unloading at port accidental spills from foundered vessels, and leaks from vessels in transit in Suez Bay; wastes from the industrial companies including; oil refineries (e.g. Sumed Pipeline Company Terminals, Nasr Petroleum Company, petro jet, and Suez Petroleum Company), fertilizer plant, Electric power stations (attaka and thermal companies) and other industries in addition to the negative impacts of coastal tourism in El-Adabiya port and El-Ain El-Sukhna (**Mohamed *et al.* 2007)**. All these refuses are discharged directly or indirectly into the bay. These refuses contain very large variety of chemical residues that may affect the water quality of this area. Thus, the objective of this study is to assess the current water quality of the northern part of suez Gulf by determining physicochemical characteristics; the levels of nutrients and the eutrophication state in terms of chlorphyll concentrations to ensure a good environment for marine life.

MATERIALS AND METHODS

Eleven surface water samples were collected seasonally, using five liters Niskin’s plastic bottle, during 2017 which cover different sites in the northern part of suez gulf (table 1 and fig 1) in addition to eight samples from the outfalls (Alzaytiat, Elkabanon, Textile Egypt Iran company, Suez Company for fertilizer, Sewage treatment plant, Al-Adabyia, Industrial treatment plant and Sumed Pipeline Company Terminals) discharged to the bay were collected. Temperature, pH and salinity were measured using Standard Checktemp®1F Pocket Thermometer, Jenway pH Bench Meter, Model 3505 and Bench top seven multimettler Toledo AG TDS/Salinity/Resistivity meter model 8603; respectively. Total suspended solids (TSS), Dissolved oxygen (DO) and Biological oxygen demand were analyzed according to the gravimetric analysis described by **APHA (2005)**, the modified winkler method, 5 day method; respectively and Oxidizable Organic Matter (OOM) according to FAO method (**FAO, 1976)**. Nutrient salts (ammonia, nitrite, nitrate, phosphate and silicate) were measured spectrophotometry according to the method of **APHA (2005)** using Beckman Du-UV Visible Single Beam Spectrophotometer.

Table 1: Longitude and Latitude of sampling locations.

No.	Name	Longitude	Latitude
I	Alzaytiat	29° 57 12.5 E	32° 32 44.6 N
II	Thermal Power Company	29° 56 54.6 E	32° 30 25.6 N
III	Textile Egypt Eran Company	29° 56 27.9 E	32° 29 27.9 N
IV	Suez Company for Fertilizer	29° 56 12.6 E	32° 29 03.3 N
V	Attaka Power Station	29° 56 48.0 E	32° 28 06.3 N
VI	AttakaPort	29° 55 08.2 E	32° 28 33 N
VII	Al-Adabyia Effluent	29° 53 52.5 E	32° 28 21.4 N
VIII	Al-Adabyia	29°53 39.6 E	32° 28 44.1 N
IX	Green Island	29° 55 04.2 E	32° 32 18.1 N
X	Petroleum pipeline company	29° 47 26.0 E	32° 26 56.0 N
XI	Ain sukhna	29° 36 38.0 E	32° 21 44.0 N

Chl-a of water samples was measured according to **Strickland and Parsons (1972)** in which a volume of 500-1000 ml of water sample was filtered using a 0.45µm membrane filter paper. The filter paper was then placed in a centrifugal tube and approximately 8 ml of 90% acetone was added and kept in a refrigerator in complete darkness for about 20 hours. The tubes were then removed from the refrigerator and let them warm up in the dark to room temperature. The content of the tube was completed to 10ml with 90% acetone and then centrifuged at 1000 rpm for 20 minutes. The clear supernatant was then transferred and measured spectrophotometry using 1cm cell at 630, 645, 665 and 750 nm wavelengths. Chl-a was calculated by the following equation:

$$\text{Chl-a } (\mu g/l) = (11.6\ E_{665} - 1.31\ E_{645} - 0.14\ E_{630})\ v/L.V$$

Where: E= the absorbance values, at wavelengths indicated by the subscripts, after correction for cell-cell blank correcting absorbance. v= volume of acetone (ml). L= cell length (cm). V= volume of filtered sample in liters.

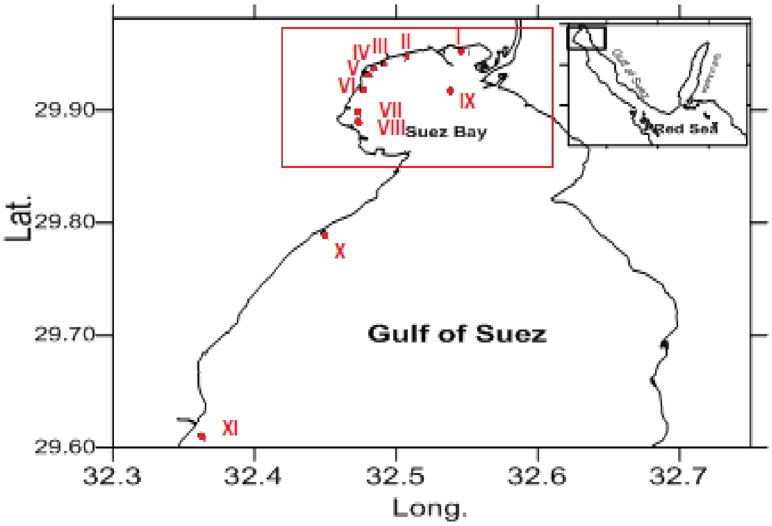

Fig. 1: Map of sampling stations of the study area.

RESULTS AND DISCUSSION

Water Temperature is an important variable that affects the biological distribution of the marine environment. It is flactuated between 17.2 ºC and 30 ºC (Table 2). The temporal distribution of water temperature was in the following order: summer > autumn > spring > winter as a result of changes in climatic condition, latitude, altitude, season, wind, depth, waves. These variations in ambient temperature may affect the rate of bacterial activity, decomposition of organic matter as well as solubility of dissolved oxygen (**Abdelmongy and El-Moselhy, 2015**). Suspended solids are one of the biggest sources of water pollution. When these suspended particles settle to the bottom of a water body, they become sediments. Suspended solids may kill fish and other aquatic fauna by causing abrasive injuries, clogging the gills and respiratory passages, blanketing the stream bottom, by destroying the spawning beds and by screening out light necessary for the photosynthetic activity of aquatic plants (**Akan *et al.* 2012**). Total Suspended solids (TSS) concentrations flactuated between 11 and 32 mg/L (Fig. 2). The annual mean concentration varied from 17.75 mg/L at Textile Egypt Iran Company to 27 mg/L at Thermal Power Company (II).

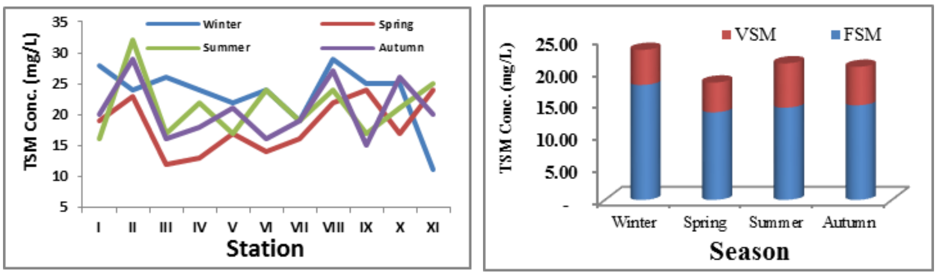

Fig. 2: The Annual and Seasonal Variations of TSM concentrations(mg/L) in water samples collected from the study area during 2017.

The maximum seasonal mean was recorded during winter and the lowest during summer. Fixed suspended matter (FSM) represented values from 32.29% to 87.5% of TSS and % VSM (volatile suspended matter) varied from 8.33 to 64.71%.

The pH value is greatly affected by the photosynthetic activity of algal biomass as well as by the amount of sewage discharged into the hot spot areas (**Abdel-Halim and Aly-Eldeen, 2016**). It is fluctuated between 7.83 and 8.17 (Table 2). The maximum seasonal mean was recorded during summer and the lowest during winter as a result of decrease of photosynthetic activity (low chl-a concentrations). Our results indicate that the pH of the Suez Bay water is suitable for the fish and aquatic organisms life around the year, where the recommended pH range for normal fish productivity is from 5 to 9 and for maximum productivity should be in the range from 6.5 to 8.5 (**Phang and Siew-Moi, 1991**).

Table 2: The range and the seasonal (average ± SD) values of physicochemical parameters of the northern part of suez gulf water during 2017.

	Temp. (°C)	pH	Salinity ‰	DO (mg/L)	OOM (mg/L)	BOD (mg/L)	TSS (mg/L)
Winter	17.2-21.8	7.83-8.16	40.09-41.04	6.92-9.09	6.0-9.2	0.9-4.15	11.0-29.00
	18.47±1.3	8.01±0.11	40.66±0.33	7.69±0.82	7.35±1.11	2.4±1.2	23.36±4.9
Spring	23.25-25.65	7.85-8.19	40.54-41.62	5.42-7.22	5.0-11.6	2.35-5.42	12.00-24.00
	23.98±0.69	8.04±0.11	41.08±0.37	6.07±0.55	9.56±1.39	3.45±0.88	18.27±4.43
Summer	29.5-29.75	7.85-8.15	41.57-42.31	5.06-7.13	6.4-10.0	3.34-4.88	16.00-32.00
	29.75±0.19	8.09±0.05	41.89±0.26	5.97±0.59	8.4±1.16	4.06±0.42	21.27±4.82
Autumn	22.9-24.9	7.79-8.15	40.87-41.84	4.52-7.68	8.0-10.8	1.35-5.6	15.0-29.0
	24.25±0.65	8.05±0.12	41.36±0.33	6.24±1.08	9.48±0.8	3.85±1.26	20.64±4.74
Annual Mean	23.69-25.11	7.97-8.11	40.89-41.55	6.11-6.92	7.57-9.6	3.0-4.0	17.75-27.00
	24.11±0.42	8.05±0.04	41.24±0.18	6.49±0.25	8.7±0.74	3.44±0.3	20.89±2.93

The EU (European Union) also sets pH protection limits of 6 to 10 for fisheries and aquatic life (**Chapman, 1993**). pH level was found to be within the range recorded of the Northern red sea (7.78-8.21) by **Abdelmongy and El-Moselhy, (2015)** and lower than that recorded of northern part of suez gulf by **Diab (2017)** and **Hamed *et al.* (2010).**

Natural water's salinity is influenced by depth, latitude and the mode of water percolation (**Abou-Taleb, 2004**). Salinity showed a spatial seasonal variation (40.09-42.31 ppt) (Table 2). The recorded high summer water salinity may be attributed to the high evaporation rate (r=0.775 with Temperature, n=44, P>0.01) as suggested by **El Gammal *et al.* (2017).** Salinity was found to be within the range recorded of Gulf of Suez by **Hamed *et al.* (2010)** and that recorded of Red sea by **Nassar *et al.* (2014).**

Dissolved Oxygen is one of the key parameters and factors in the chemical and biological systems of natural waters that affect on survive, activity, biological processes and production of fish and almost all aquatic organisms (**Goher *et al.* 2018**), on the other side, the too high or too low levels of the dissolved oxygen can harm aquatic life and affect water quality. The water of Suez Bay was oxygenated around the year and suitable for aquatic organisms and fish life, according to “MINNESOTA RULES” water of class 2B sets a 5- milligrams-per-liter standard of dissolved oxygen, for cool or warm water fish (**MPCA, 2019**). The present results showed that DO fluctuated between 4.52 mg/l during autumn at Ain Sukhna and 9.09 mg/L during winter at Suez Company for Fertilizer with an annual average of 6.51 mg/l (Fig. 3). The maximum DO values were observed during winter that may be attributed to low temperature values that increased solubility of gasses (r=-0.49 with temperature, n= 44, p< 0.01) and low OOM (r=-0.37, n= 44, p< 0.01). This result agrees with the fact that oxygen solubility decreases with increasing temperature and salinity as reported by **Calliari *et al*. (2005)**. BOD is one of the most important parameters to assess the degree of water pollution with organic pollutants **(Abdelmongy and El-Moselhy, 2015).**

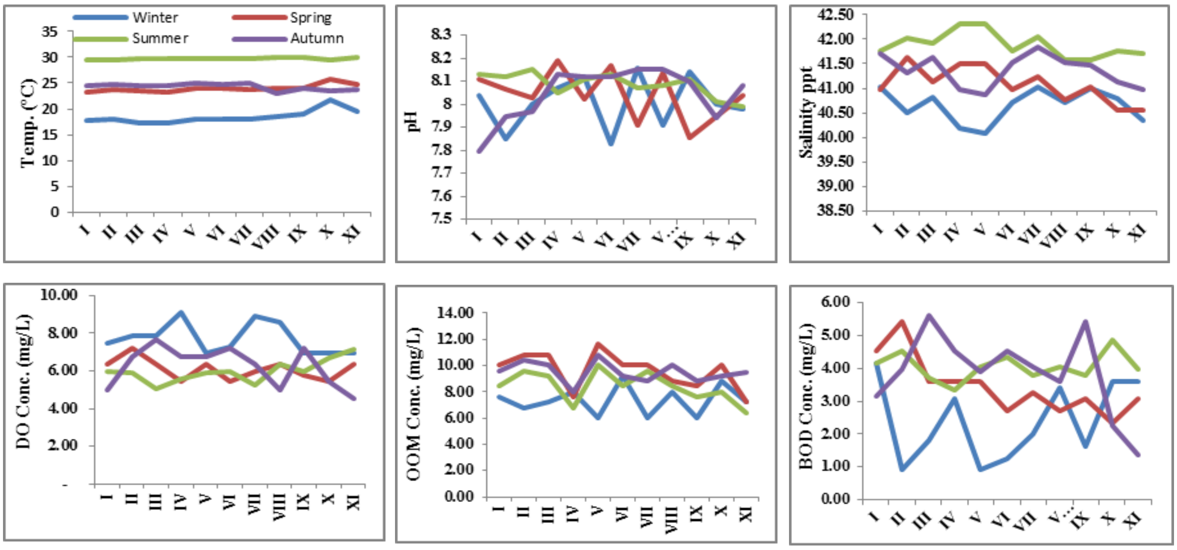

Fig. 3: Temp. (ºC), pH, Salinity (‰), DO, OOM and BOD (mg/l) fluctuations of water samples collected from the study area during 2017.

The annual Mean Concentration varied from 3.00 mg/L at Ain Sukhna to 4 mg/L at Alzaytiat. ANOVA results showed a spatial significant difference in BOD values (P< 0.01). The maximum seasonal mean was recorded during summer that may be attributed to high temperature (r=0.533, n= 44, p< 0.01) that increased biodegradation of organic matter and the lowest during winter that may be attributed to low OOM concentrations (r=0.378, n= 44, p< 0.05). BOD concentrations were found to be within the range (1.36-7.95 mg/L) recorded of Suez Canal by **Soliman *et al.* (2015)** but lower than that recorded of Suez Gulf (1.53-7.04 mg/L) by **Diab (2017).**

Oxidizable organic matter, (OOM) is used as a useful criteria to assess sewage pollution and organic loading (**Abdel-Halim and Aly-Eldeen, 2016**). OOM concentrations showed spatial and temporal variations (P<0.01) and it ranged between 6 mg/L and 11.60 mg/L. Attaka power Company recorded the maximum annual mean concentration of OOM (9.6 mg/l). The maximum seasonal mean was recorded during spring and the lowest during winter.

Table 3: The range and seasonal (average ± SD) values of Nutrient Salts of the northern part of Suez Gulf water during 2017.

	Ammonia (µM)	Nitrite (µM)	Nitrate (µM)	Phosphate (µM)	Silicate (µM)
Winter	5.0-11.24	0.84-2.68	3.84-16.59	0.37-1.57	0.84-3.63
	6.85±1.97	2.03±0.6	10.69±3.98	0.84±0.34	1.47±0.8
Spring	2.88-12.44	1.11-6.25	4.65-14.59	0.48-2.22	1.86-6.23
	7.62±2.93	4.72±1.68	10.1±2.82	1.74±0.64	4.58±1.12
Summer	2.44-7.04	0.65-3.62	3.36-16.49	1.11-3.49	6.6-18.41
	3.81±1.41	2.26±1.05	10.77±3.85	2.52±0.74	9.52±3.32
Autumn	6.56-13.36	2.87-4.41	5.67-8.75	0.79-6.08	6.23-8.28
	10.27±2.25	3.69±0.54	7.45±0.85	1.78±1.72	7.21±0.74
Annual	4.35-9.28	1.56-4.14	5.15-12.99	1.26-2.43	4.65-8.0
Mean	7.14±1.65	3.18±0.88	9.75±2.44	1.72±0.33	5.7±0.88

Ammonia may be used as a good indicator for the degree of water pollution. It is a highly variable parameter that quickly produced and processed by the bacterial decomposition of organic matter (ammonification) (**Abu Hilal and Abu Alhaija, 2010).** The results of ANOVA showed temporal and spatial variations (P>0.01) between 2.44 µmol/L at Green Island during summer and 13.36 µmol/L at Textile Egypt Iran Company during Autumn (Fig. 4). The maximum seasonal mean was (10.27 mg/L) during autumn and the lowest 3.81 µmol/L during summer.Ammonia levels were found to be within the range recorded of Northern Red Sea (2.41-12.56) by **Abdelmongy and El-Moselhy (2015)** but lower than that recorded of Suez Canal (0.26-22.12) and Suez Gulf (3.24-43.15) by **Soliman *et al.* (2015)** and **Diab (2017);** respectively. Dissolved inorganic nitrogen (DIN) includes the sum of ammonia, nitrite and nitrate concentrations. Ammonia comprises about 35.54% of DIN.

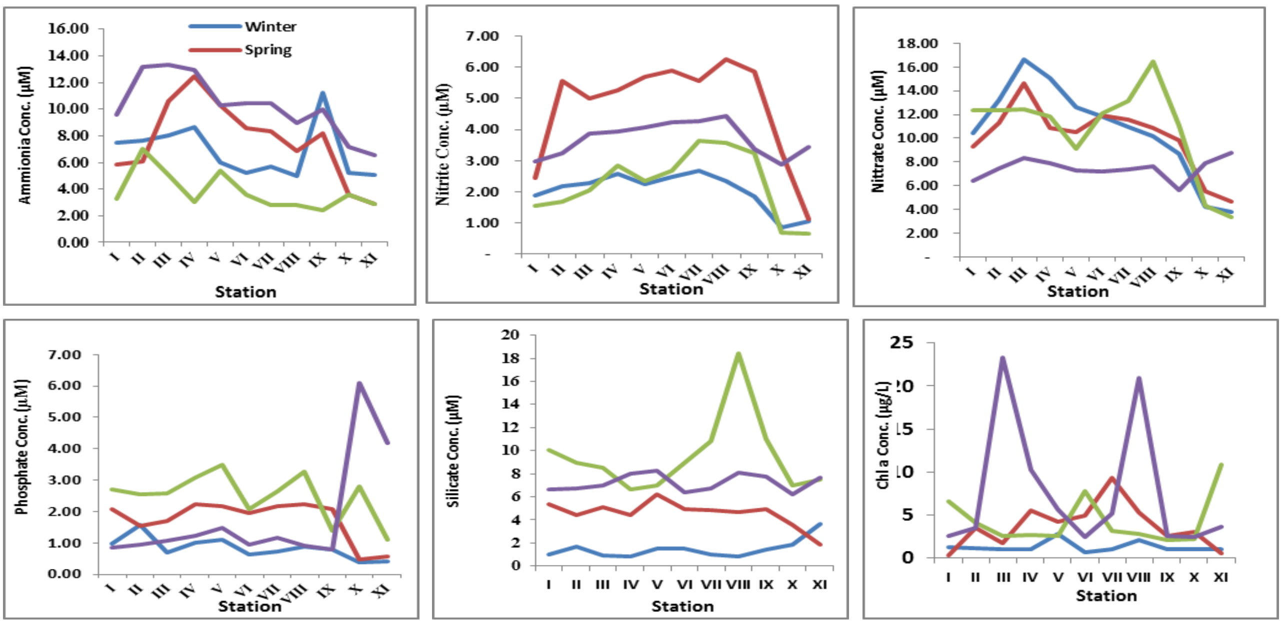

Fig. 4: The seasonal Variations of ammonia, nitrite, nitrate, phosphate, silicate (µM) and Chl a (µg/l) concentrations in the northern part of Suez Gulf water during 2017.

Nitrite is an intermediate compound that could be derived either from the oxidation of ammonia or reduction of nitrate and can be removed from solution during nitrogen assimilation by phytoplankton. It comprises only 15.38 % DIN. Nitrite concentrations showed spatial and temporal variations between 0.84 µmol/L at

Petroleum pipeline company during winter and 6.25 µmol/L at Al-Adabyia during spring (Fig. 4). The annual mean concentration varied from 1.56µmol/L at Ain Suhkna to 4.14µmol/L at Al-Adabyia that may be attributed to anticlockwise water circulation that bring large amount of pollutants at Al-Adabyia (**Soliman *et al.* 2017**). The maximum seasonal mean (4.72 µmol/L) was recorded during spring that may be attributed to the excretion of extracellular nitrite by phytoplankton and the lowest (2.03 µmol/L) during winter that might be attributed to the increase in the oxidation rate of nitrite to nitrate in the presence of high DO concentration. Nitrite levels were reported to be higher than that recorded of the northern sector of Suez Gulf (0.77-2.82) and (0.70-4.95) µmol/L by **Diab (2017)** and **Hamed *et al.* (2010)** and that recorded of the Northern red sea (0.07-0.12) and (0.028-0.408) µmol/L by **Abdelmongy and El-Moselhy (2015)** and **Nassar *et al.* (2014)** but lower than that recorded of Suez Canal (0.05-16.83) µmol/L by **Soliman *et al.* (2015)**.

Nitrate is the most stable form of inorganic nitrogen in oxygenated water. It is the end product of the nitrification process in natural water. The maximum seasonal mean was (10.77µmol/L) recorded during summer and the lowest (7.45 µmol/L) during autumn that could be attributed to assimilation by plants in addition to the denitrification process (i.e. the reduction of nitrate to nitrite before releasing N_2O or N_2 molecules). Nitrate comprises the majority of DIN and represents about 49.08% DIN. Nitrate levels were found to be lower than that reported of the Northern sector of Suez Gulf (2.07-67.88), (4.64-20.85) µmol/L by **Diab (2017); Hamed *et al.* (2010)** and that recorded of Suez Canal (1.04-25.33) µmol/L by **Soliman *et al.* (2015)** but higher than that reported of Northern Red sea (0.43-3.17); (0.170-1.205) µmol/L by **Abdelmongy and El-Moselhy (2015) and Nassar *et al.* (2014).**

Phosphorus is one of the most important elements controlling the growth and reproduction of phytoplankton and can be considered as the most phosphorus form readily available for algal uptake (**Abdelmongy and El-Moselhy, 2015**). The results of ANOVA showed significant variations of Phosphate Concentrations between seasons that flactuated between 0.37 and 6.08µmol/L (Fig. 4). The maximum seasonal mean was (2.50 µmol/L) during summer and lowest 0.82 µmol/L during winter. The low concentrations at most locations of the present study may be related to its short residence time in seawater. The range of phosphate concentrations were found to be higher than that reported of Northern part of Suez Gulf (0.93-3.59); (0.32-3.04) µmol/L by **Diab (2017)** and **Hamed *et al.* (2010)** and that recorded of Suez Canal (0.03-2.11) µmol/L by **Soliman *et al.* (2015)** and that recorded of Northern red sea (0.08-0.38) and (0.007-0.413) µmol/L by **Abdelmongy and El-Moselhy (2015) and Nassar *et al.* (2014)**. Silicon is an abundant element in the universe and is considered as an important nutrient in the marine environment since some marine organisms such as diatoms and radiolaria utilize this form of nutrient for growth and the formation of skeletal material (**Abdel-Halim and Aly-Eldeen, 2016**). Silicate Concentrations showed temporal variations from 0.84 µmol/L at Suez Company for Fertilizer during winter to 18.41 µmol/L at AL-Adabyia during summer (Fig. 4) that may be due to anticlockwise water circulation in suez bay.

The N: P ratio appeared to be an important, ecological parameter because it gives account for dominance and succession of algal species and eutrophication (**Smith, 1983**). **Riley and Skirrow (1967)** showed that a relatively constant N:P molar ratio of 15:1 (7:1 mass ratio) was found statistically on a world scale. Generally, the N:P ratio varies from one location to the other depending on the seasonal variability of quality and quantity of wastes discharged into the study area. In this connection; Generally, water bodies with a TN:TP molar ratio < 10 are considered to be N limited, whereas those with TN:TP molar ratios >20 are considered to be P deficient (**Elsayed *et al.* 2019**).The present study showed DIN/DIP ratios fluctuated between 2.95 at Petroleum pipeline company during autumn and 39.17 at Textile Egypt Iran Company during winter that may be due to the direct discharge of wasted effluents enriched with nitrogen with annual average of N/P ratio for whole area was (16.14). The N/P molar ratio indicates that the different sites in the northern part of Suez Gulf are, either, N limited or P limited or N/P collimated phosphorus is the most limiting factor. The annual average of N/P ratio for whole area was (16.14).

Chlorophyll (Chl-a) is a green pigment found in most photosynthetic organisms. It absorbs sunlight and converts it to sugar during photosynthesis. It is used as a measure for living plant matter in the particulate organic matter in water (**Khamis, 2010**) as well as being an indicator of phytoplankton abundance and biomass in waters (**Nessim, 2005**). It is also used as a trophic state indicator (**Faragallah, 2004**). Chlorophyll-a varied between 0.98 and 23.27 µg/l, where the maximum concentration was recorded during autumn as a result of high photosynthetic activities and the lowest was during winter.

Chemical characteristics of different effluents discharged to the study area.

Table 4 shows physicochemical parameters and nutrient salts concentrations discharged from some factories in the study area.Temp. flactuated between 16 ºC at Sewage treatment plant to 22.4 ºC at Summed Pipeline Company Terminals. pH fluctuated between 7.94 at Sumed Pipeline Company Terminals and 8.28 at industrial sewage. The maximum ammonia concentration (287.60 µM) was discharged from Suez Company for Fertilizer followed by Sewage treatment plant (208.0 µM) while Sumed Pipeline Company Terminals discharged the lowest concentrations (3.24 µM). Sewage treatment plant discharged the maximum concentrations of phosphate, silicate and nitrite (7.94, 138.57 and 77.38 µM); respectively. OOM values ranged from 20 mg/l at Al-Adabyia and Elkabanoon effluent to 104 mg/l at Sewage treatment plant as in Table 4. Textile Egypt Iran effluent discharged the maximum TSM concentrations (187.00 mg/l). The maximum VSM% was 90.00 % at Sewage treatment plant.

Table 4: Physicochemical Parameters and Nutrient Salts Concentrations Discharged from some factories in the study area.

Company / Parameter	Alzaytiat	Elkabanon	Textile Egypt Iran Company	Suez Company for Fertilizer	Sewage treatment plant	Al Adabyia	Industrial treatment plant	Sumed Pipeline Company Terminals
Temp. (ºC)	18.00	17.00	18.00	20.00	16.00	18.00	18.00	22.40
pH	8.11	8.21	8.20	8.79	8.01	8.24	8.28	7.94
Salinity ‰	35.40	34.60	35.60	30.70	2.03	36.60	13.40	
OOM (mgl $^{-1}$)	24.00	20.00	28.00	68.00	104.00	20.00	60.00	26.00
Ammonia (µM $^{-1}$)	61.60	75.60	76.00	287.60	208.00	82.00	53.20	3.24
Nitrite (µM $^{-1}$)	13.39	11.90	16.86	46.62	77.38	13.89	15.38	2.38
Nitrate (µM $^{-1}$)	56.57	50.14	46.50	280.74	80.36	51.45	292.18	16.35
Phosphate (µM $^{-1}$)	1.59	1.06	2.65	4.23	7.94	1.06	4.76	0.85
Silicate (µM $^{-1}$)	19.53	18.60	16.74	19.53	138.57	16.74	203.67	41.32
TSM (mgl $^{-1}$)	23.00	13.00	187.00	24.00	10.00	11.00	11.00	60.00
FSM (mgl $^{-1}$)	16.00	11.00	139.00	16.00	1.00	8.00	7.00	44.00
VSM (mgl $^{-1}$)	7.00	2.00	48.00	8.00	9.00	3.00	4.00	16.00
FSM%	69.57	84.62	74.33	66.67	10.00	72.73	63.64	73.33
VSM%	30.43	15.38	25.67	33.33	90.00	27.27	36.36	26.67

Application of Factor Analysis on Water

Principal component analysis (PCA) was applied for multivariate data derived from the water quality parameters analysis of surface water samples of the northern part of suez gulf during 2017 (n=44). The data contain 18 variables, Table 5. Factor extraction was done with a minimum acceptable Eigen value greater than one. The output data revealed that five factors (PC1, PC2, PC3, PC4 and PC5) affected water parameters with cumulative covariance of 76.937 %. Varimax rotated components matrix gave an overview on the nature of loading among the parameters (Fig. 5).

Table 5: Factor Loadings (Varimax raw) of water parameters of the northern part of suez gulf during 2017.

Rotated Component Matrix[a]					
	Component				
	PC1	PC2	PC 3	PC4	PC5
DO	-.837	-.071	-.149	.139	-.164
Phosphate	.773	.047	-.020	.313	-.059
Temp	.669	.650	-.175	-.075	.122
BOD	-.016	.845	.130	-.198	.118
Salinity	.474	.724	-.018	.074	.021
Silicate	.592	.640	.011	.128	.098
Chla	-.096	.572	.443	-.084	-.070
Nitrite	.180	-.024	.819	.255	.231
Ammonia	-.373	.041	.764	-.007	.072
OOM	.399	.198	.697	-.145	-.067
Nitrate	.089	-.150	.085	.901	-.048
TSS	-.164	.040	-.241	.214	-.831
pH	-.062	.383	-.118	.419	.656
Total	4.046	2.108	1.599	1.186	1.037
% of Variance	31.124	16.214	12.297	9.124	7.980
Cumulative %	31.124	47.338	59.635	68.759	76.739

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 14 iterations.

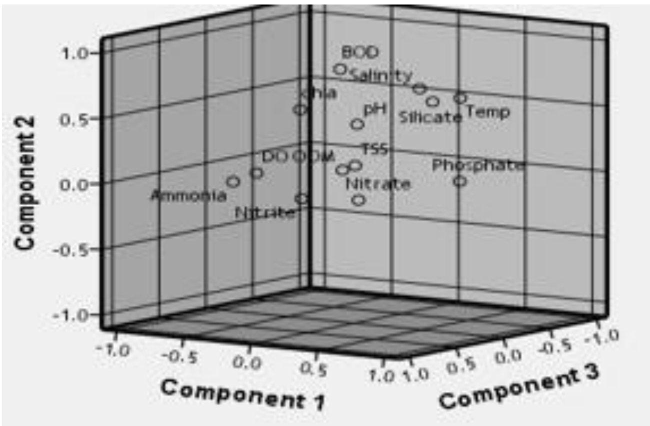

Fig. 5: Component plot in rotated space.

PC1 represented 31.124 % of the total variance. It was characterized by a positive loading on Temperature (0.669), salinity (0.474), phosphate (0.773), silicate (0.592) and a negative loading on DO (-0.837). This component reflected the positive correlation between temperature and salinity that in turn decreases DO solubility. PC2 represented 16.214 % of the total variance. This factor was characterized by a positive loading on temperature (0.650), salinity (0.724), silicate (0.640), BOD (0.845) and Chl a (0.572). PC3 represented 12.297 % and was characterized by positive loading on Chl a (0.443), Nitrite (0.819), Ammonia (0.764) and OOM (0.697). Chl a loads on PC2 and PC3 that reflected the effect of high concentrations of silicate, ammonia and nitrite in raising photosynthetic activities and increasing chl a concentrations. PC4 represented 9.124 % and was characterized by positive loading on Nitrate (0.901) and pH (0.419). PC5 represented 7.980% of the total variance and was characterized by a negative loading on pH (-0.831) and a positive loading on TSS (0.901). This component reflected the role of TSS in decreasing pH values by reducing light penetration necessary for photosynthesis (increased the formation of carbonic acid).

Water quality index (WQI)

Numerous water quality index has been formulated all over the world which can easily judge out the overall water quality within a particular area promptly and efficiently (**Bharti and Katyal, 2011**). Water Quality Index (WQI) was calculated according to the following formula (**Saleh, 2006 and El Zokm, 2010**).

$$\mathbf{WQI=\sum^{n}_{n=1} (\lambda_n/\sum\lambda)\times PCn}$$

Where: n: The number of effective components, λ_n: the Eigen values of the effective components, Σ_λ: sum of the Eigen values and PC_n: the n critical principal component scores.

Where: PC1, PC2, PC3, PC4 and PC5: Principal component factor scores, bold number: high effect of factor scores.

High values of principal component factor scores mean that this location is a hot spot. According to PCA data, Al-Adabyia, Al-Adabyia Effluent, Textile Egypt Eran Company and Attaka Power Station are considered as hot spots in the Northern part of Suez gulf. The PC1, PC2 and PC4 affected highly on pollution of Al-Adabyia that may be attributed to anticlockwise water circulation. The PC1 affected on pollution of Al-Adabyia Effluent, Textile Egypt Eran Company and Attaka Power Station, Table 6.

Table 6: Evaluation of Hot Spots in the area of investigation based on factor scores calculations.

Hot Spots	PC1	PC2	PC3	PC4	PC5	WQI	Parameters
Al-Adabyia (Summer)	0.5449	0.2377	-0.1303	0.2572	-0.0561	0.8535	PC1: Temperature (0.669), salinity (0.474), phosphate (0.773), silicate (0.592) DO (-0.837) PC2: Temperature (0.650), salinity (0.724), silicate (0.640), BOD (0.845) and Chl a (0.572). PC4: Nitrate (0.901) and pH (0.419).
Al-Adabyia Effluent (Summer)	0.6488	0.1088	-0.0614	0.0806	0.0181	0.7949	PC1: Temperature (0.669), salinity (0.474), phosphate (0.773), silicate (0.592) DO (-0.837)
Textile Egypt Eran Company (Summer)	0.5006	0.0938	-0.1183	0.0552	0.0952	0.6265	PC1: Temperature (0.669), salinity (0.474), phosphate (0.773), silicate (0.592) DO (-0.837)
Attaka Power Station (summer)	0.5248	0.1356	-0.0778	-0.0149	0.0536	0.6211	PC1: Temperature (0.669), salinity (0.474), phosphate (0.773), silicate (0.592) DO (-0.837)

CONCLUSIONS

This study discussed the levels of the physicochemical characteristics, nutrient salts and organic matter in terms of COD and BOD values; in addition to the assessment of water quality in the northern part of Suez Gulf, that is exposure to different sources of pollution (ports, power stations, fertilizer, petroleum oil refineries, steel industry, others). High load of organic matter and nutrients was indicated. PCA referred to the relations between parameters and hot spot locations of the study area, indicating that Al-Adabyia, Al-Adabyia Effluent, Textile Egypt Eran Company and Attaka Power Station are the more polluted sites in the investigated area.

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