

## Water characteristics of the Western side along the Gulf of Suez (Red Sea) during (2014-2015)

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### ABSTRACT

Physico-chemical parameters and nutrient salts were determined seasonally in water samples collected from 14 stations along the western side of the Gulf of Suez during the period from spring 2014 to winter 2015. The results indicated that, the annual mean range for the surface water samples collected from the north-western sector of the study area (water temperature, salinity, pH, dissolved oxygen, biological oxygen demand, nitrite, nitrate, ammonia and dissolved inorganic phosphate) were 18.40-30.10<sup>0</sup>C, 39.90-40.51 ‰, 8.08-8.39, 4.28-10.41 mgO<sub>2</sub>L<sup>-1</sup>, 1.53-7.04 mgO<sub>2</sub>L<sup>-1</sup>, 0.77-2.82 μmolL<sup>-1</sup>, 2.07-67.88 μmolL<sup>-1</sup>, 3.24-43.15 μmolL<sup>-1</sup> and 0.93-3.45 μmolL<sup>-1</sup>, respectively. The corresponding values for surface water samples collected from the south-western sector of the study area were 17.70-33.30<sup>0</sup>C, 40.45-40.88‰, 8.16-8.37, 4.36-10.71 mgO<sub>2</sub>L<sup>-1</sup>, 1.53-6.73 mgO<sub>2</sub>L<sup>-1</sup>, 1.12-2.53 μmolL<sup>-1</sup>, 5.27-11.48 μmolL<sup>-1</sup>, 1.94-10.80 μmolL<sup>-1</sup> and 1.87-4.77 μmolL<sup>-1</sup>, respectively.

Generally, the present data indicated that the concentration of the measured Physico-chemical parameters were relatively high especially (the level of nutrient salts) at the north-western of the Gulf and decreased southward (Red Sea). This reflects high intensive disposal of sewage and industrial effluents in the north-western sector of the Gulf of Suez.

Seasonally, nutrient salts levels increased during spring and summer which may be attributed to increased human and industrial activities and disposal of treated and untreated sewage. Nutrient salts decreased during autumn, except for phosphate.

The annual average of N:P ratio was 10.83 for surface water samples in the north-western sector, while it was 4.68 in the south-western sector of the Gulf of Suez. The results of N:P ratio indicated that the north-western sector of the Gulf of Suez is in the eutrophic state, mainly due to the high load of nitrogenous compounds especially ammonia.

Results of the present study reflect that the north-western sector of study area adverse from high intensive disposal of sewage and industrial effluents.

**Keywords:** Physico-chemical parameters, nutrient salts, and the Gulf of Suez.

### INTRODUCTION

Water quality criteria is not only intended to protect essential and significant life in water, as well as the direct users of water, but also to protect life that is dependent in water for its existence, or that may consume intentionally any edible portion of such life. Also, the assessment of physico-chemical parameters and nutrients (water quality) are one of the most important indicators for the extent of pollution in the marine environment. The problems of sewage pollution of the Gulf of Suez waters have become a point of local concern. Signs of this kind of pollution have already been observed in the last few years along the coast of the Suez Gulf (Soliman, 1999). The disposal of untreated sewage may be harmful concerning its possible hygienic and aesthetical effects and its impact on fauna and flora in the marine environment.

The hydrography and chemistry of the Suez Gulf were studied by several authors Hamed and Said, (2000) and Fahmy *et al.*, (2005). The nutrient salts concentrations in the

Gulf of Suez increase gradually from the south to north (Hamed, 1996). So the relation between human activities and environmental changes in the Gulf of Suez require knowledge of trends in water characteristics. The Gulf of Suez is one of arms of Sinai Pensiula. It is located in the northwest of the Red Sea. The geographical position of the Gulf of Suez makes it an important shipping route for oil tankers in the Middle East. It extends from Port-tawfik in north in Suez City to Gemsa in south, with overall length 280 km., width (20-40) km. and 45 m. water depth (Beltegy, 1983). The aim of this work is to evaluate the levels of some physic-chemical parameters and nutrient salts in water samples collected along the western side of the Gulf of Suez.

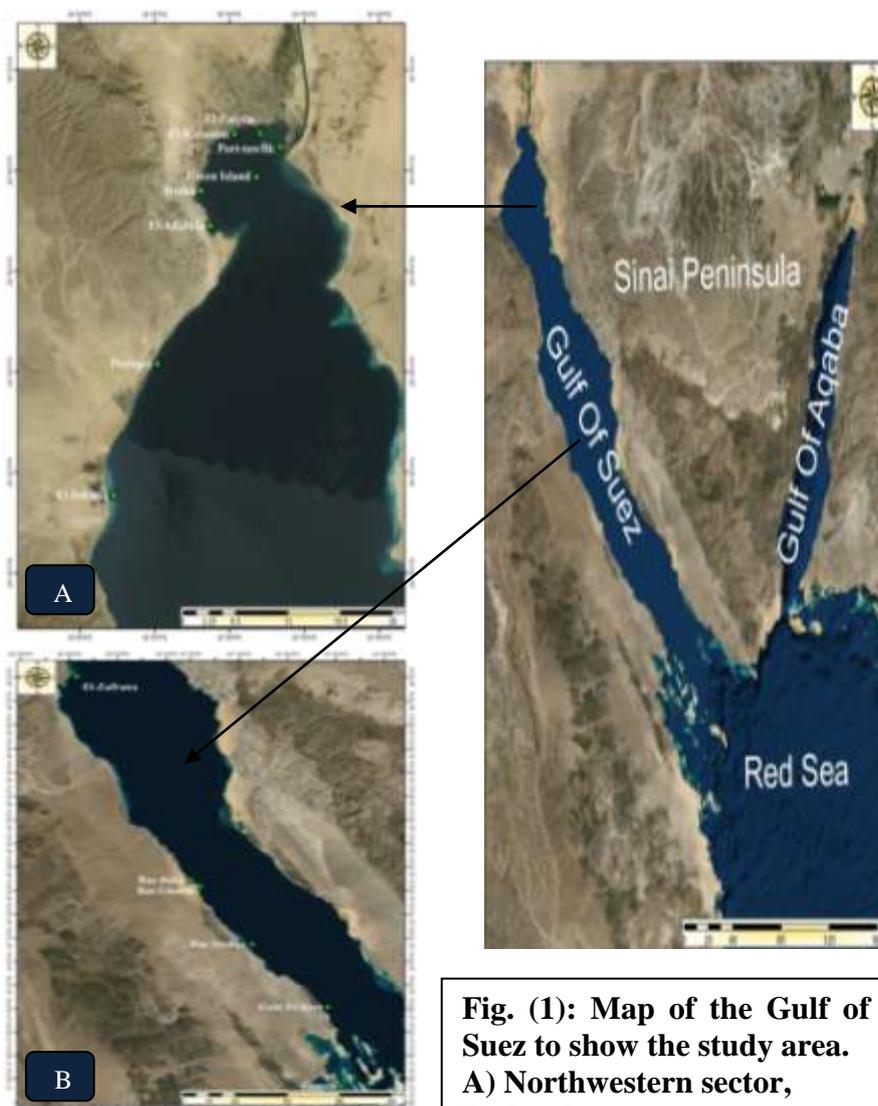
## MATERIALS AND METHODS

### Description of the study area

The western side of the Gulf of Suez was divided into two sectors (Fig. 1).

**Sector A (Northwestern sector):** its water is mainly affected by industrial and domestic wastes. It is represented by stations (I: Port-tawfik, II: El-Zaiytia, III: El-Kabanon, IV: Attaka, V: El-Adabyia, VI: Green Island, VII: Petroget and VIII: El-Sokhna).

**Sector B (Southwestern sector):** its water is mainly affected by different petroleum activities. It is represented by stations (IX: El-Zafrana, X: RasBakr, XI: RasGharib, XII: RasShoker, XIII: Gebl El-Zeet and XIV: Gemsa).



**Fig. (1):** Map of the Gulf of Suez to show the study area.  
**A) Northwestern sector,**  
**B) Southwestern sector.**

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### 2. Samples collection and storage

Water samples were collected seasonally through spring, summer, autumn of 2014 and winter 2015. Water temperature was measured by using a simple pocket thermometer graduated to 0.1 °C. The pH value of water samples were determined by using portable pH meter (Orion model 210 digital). Salinity was determined using salinometer (model YSI 33). Dissolved oxygen and biological oxygen demand (BOD) were measured according to (APHA, 2005). The dissolved nutrients salts were analyzed immediately in water samples. Nitrite, nitrate, ammonia and dissolved inorganic phosphorous were measured spectrophotometrically according to the method described by Parsons *et al.* (1984) by using US-visible single beam spectrophotometer (Beckman model DU6).

## RESULTS AND DISCUSSION

### 1. Physico-chemical parameters

In the present study, the highest mean temperature (30.10-33.30 °C) was found at St.IV and St.XIV (Attaka and Gemsa), while the lowest value (18.40-17.70°C) was found at St. II and St.X (El-Zaiytia and RasBakr) (Tables 1 & 2). Generally, the maximum mean value was recorded in summer and the minimum one was recorded in winter. These variations in water temperature mainly depended on weather conditions (solar radiations, wind, wave, water circulation and seasonal changes in air temperature) and partially on the time of sampling (Khalil *et al.*, 2014).

Salinity showed a narrow range of variations between stations (Tables 1 & 2) and (Fig. 2). Generally, the results indicated that, salinity increases from southward to northward, where it ranged between (39.90-40.51‰) at St. III and St. II (El-Kabanon and El-Zaiytia) at the northwestern sector, this is probably due to the disposal of the treated and untreated sewage and industrial effluents from the nearby factories. It fluctuated between (40.45-40.88) at St.IX and St.XIV (El-Zafrana and Gemsa). The results indicated that the salinity of water reached its maximum during (warm season) summer and the minimum during (cold season) winter. This may be attributed to evaporation of water by elevation of temperature. Evaporation must be considered as one of the most controlling factors for salinity and consequently density, circulation and sea level variation (Maiyza, 1988).

pH is of the vital environmental characteristics for the survival, metabolism, physiology, growth of aquatic organisms and chemical processes (Ramanathan *et al.*, 2005). The values of pH varied within narrow limit as shown in Tables (1 & 2) and Figure (2). On the northwestern sector, the mean values of pH ranged between (8.08-8.39) at St. III and St.VI (El-Kabanon and Green Island), this is may be related to the fact that this location is affecting by disposal of treated and untreated sewage and industrial effluents from the nearby factories, and the minimum pH value was recorded in location far away of any pollution sources. Also, it differentiated between (8.16-8.37) at St.X and St.XII (Ras Bakr and Ras Shoker). Annually, the highest mean pH (8.36) was found at Ras Shoker and the lowest one (8.12) was recorded at Green Island. Relatively the higher pH values were recorded during summer (8.35) in which the rise in temperature usually causing more consumption of carbon dioxide due to the phytoplankton photosynthetic activity. On the other hand, lower pH values were observed during winter (8.11) in which there is an increasing in CO<sub>2</sub> level due to increasing of the rate of organic matter decomposition by the microbial respiration.

Tables (1 & 2) and Figure (2) presented the mean concentrations of DO in water samples collected from the western sector of the Gulf of Suez. On the northwestern sector, the fluctuations of DO content varied between (4.28-10.41 mgO<sub>2</sub>L<sup>-1</sup>) at St.III and St.IV (El-Kabanon and Attaka), this may be due to increased disposal of untreated sewage from Suez City. On the other sector, the levels of DO content ranged between (4.36-10.71 mgO<sub>2</sub>L<sup>-1</sup>) at

St.XII and St.XIII (Ras Shoker and Gebl El-Zeet). Annually, the highest mean DO ( $7.97\text{mgO}_2\text{L}^{-1}$ ) was recorded at Gebl El-Zeet and the lowest one ( $5.89\text{mgO}_2\text{L}^{-1}$ ) at Port-tawfik. Seasonally, the maximum mean recorded DO ( $9.08\text{mgO}_2\text{L}^{-1}$ ) was during winter and the minimum ( $4.76\text{mgO}_2\text{L}^{-1}$ ) was during summer. The above mentioned results indicated that, the dissolved oxygen values increased during winter, this probably attributed to activities of air movement allowing more transfer of oxygen across the air-water interface and active water mixing and gas exchange (Hamed *et al.*, 2012), while it decreased during summer, this is may be due to increased human activities and disposal of untreated sewage. This high oxygen content indicates a good mixing in the water column especially during winter (Girgis, 1980). This may be attributed to the increase of temperature during the summer, which causes decreasing in the degree of solubility of atmospheric oxygen gas and due to the increase in oxygen consumption during decomposition of organic matters and the oxidation of chemicals from effluents of different sources (Cole, 1979). In the present study, the results agree with result reported by UNESCO/WHO (1973), where the coastal waters require minimum value of oxygen  $4.0\text{mgO}_2\text{L}^{-1}$  and it will be better with  $5.0\text{mgO}_2\text{L}^{-1}$  for optimum ecosystem function.

In the present study BOD showed a wide range of variations as shown in Tables (1 & 2) and Figure (2).The highest mean value recorded ( $7.04\text{mgO}_2\text{L}^{-1}$ ) was at St.III (El-Kabanon), this is due to increase of human activities and disposal of untreated sewage from Suez City. Also, the lowest mean recorded ( $1.23\text{mgO}_2\text{L}^{-1}$ ) was at St.VIII (El-Sokhna). On the other hand, BOD ranged between the maximum level ( $6.73\text{mgO}_2\text{L}^{-1}$ ) observed at St.XIII (Gebl El-Zeet) and the minimum level ( $1.53\text{mgO}_2\text{L}^{-1}$ ) observed at St.IX (El-Zafrana).The maximum annual recorded ( $4.94\text{mgO}_2\text{L}^{-1}$ ) was at Petroget, while the minimum one ( $2.49\text{mgO}_2\text{L}^{-1}$ ) was at Green Island. Seasonally, the highest mean BOD ( $4.58\text{mgO}_2\text{L}^{-1}$ ) was during summer season, due to increased flourishing of phytoplankton and photosynthesis activity, increased human activities and extensive disposal of treated and untreated sewage and discharge of industrial effluents (Khalil *et al.*, 2011). On the other hand, the lowest mean ( $3.13\text{mgO}_2\text{L}^{-1}$ ) was during spring season, this may be attributed to decrease temperature slightly and related to the basis of low activity of microorganisms during cold season (Emara *et al.*, 2013). While, seasonal BOD means varied between ( $2.08$  and  $4.44\text{mgO}_2\text{L}^{-1}$ ) at summer and autumn seasons, respectively.The BOD of the Gulf is slightly high indicating the presence of load of disposal of sewage, agriculture, industrial and petrochemical effluents. In the present study, the results of BOD comparable with other recorded by Anon (1975) except El-Kabanon which recorded relatively high levels, this is may be due to increased human activities and disposal of treated and untreated sewage from Suez City.

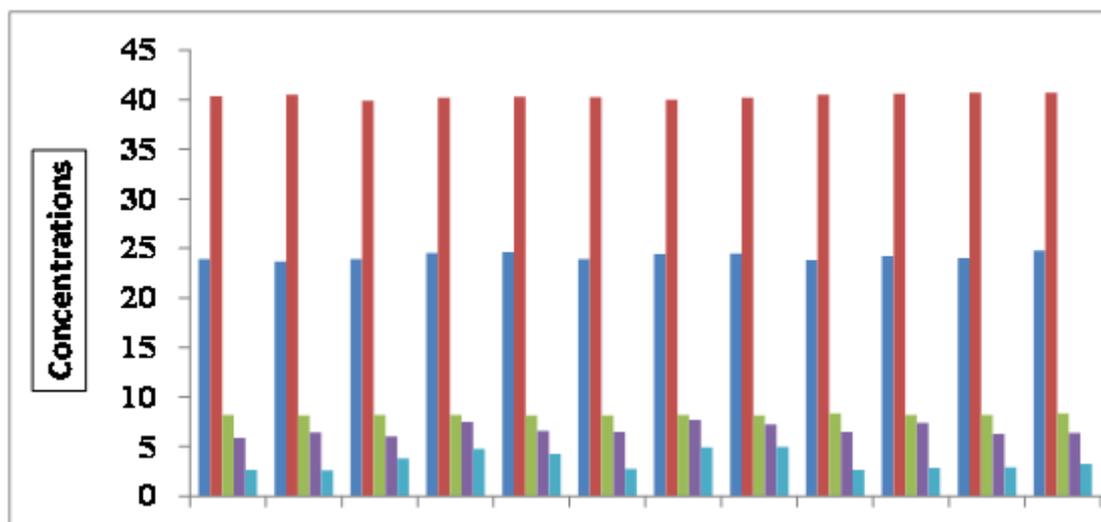
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**Table (1): Mean concentrations of physico-chemical parameters in water samples collected from the Western sector of the Gulf of Suez during spring and summer (2014).**

Seasons										
P. St.	Spring (2014)					Summer (2014)				
	T C <sup>0</sup>	S‰	pH	DO mgO <sub>2</sub> L <sup>-1</sup>	BOD mgO <sub>2</sub> L <sup>-1</sup>	T C <sup>0</sup>	S‰	pH	DO mgO <sub>2</sub> L <sup>-1</sup>	BOD mgO <sub>2</sub> L <sup>-1</sup>
I	23.70	40.39	8.21	4.44	2.60	29.40	40.40	8.29	4.74	2.14
II	23.40	40.50	8.24	7.65	4.44	29.30	40.52	8.21	4.99	1.68
III	23.80	39.91	8.18	5.51	7.04	29.60	39.99	8.39	4.28	4.74
IV	24.50	40.19	8.19	9.18	3.06	30.10	40.20	8.22	4.89	4.13
V	24.90	40.31	8.25	7.65	6.27	29.90	40.33	8.22	4.74	5.20
VI	23.80	40.22	8.10	7.71	3.67	29	40.28	8.20	4.88	3.21
VII	24.90	40.0	8.22	7.36	5.97	30	40.08	8.30	6.27	4.44
VIII	25.50	40.19	8.18	7.19	5.51	29.90	40.28	8.23	4.89	5.82
IX	28.10	40.49	8.36	6.89	2.45	27	40.57	8.33	5.06	1.53
X	28.70	40.60	8.22	7.35	2.14	27.60	40.64	8.25	6.11	1.99
XI	26.50	40.70	8.33	5.35	2.29	29	40.74	8.35	4.99	2.11
XII	28.10	40.69	8.37	5.67	1.99	30.80	40.75	8.37	4.36	2.14
XIII	28.20	40.80	8.28	6.87	2.75	30.50	40.86	8.31	5.11	1.68
VIX	27.10	40.81	8.32	5.39	3.99	33.30	40.88	8.36	5.14	3.06

**Table (2): Mean concentrations of physico-chemical parameters in water samples collected from the Western sector of the Gulf of Suez during autumn (2014) and winter (2015).**

Seasons										
P. St.	Autumn (2014)					Winter (2015)				
	T C <sup>0</sup>	S‰	pH	DO mgO <sub>2</sub> L <sup>-1</sup>	BOD mgO <sub>2</sub> L <sup>-1</sup>	T C <sup>0</sup>	S‰	pH	DO mgO <sub>2</sub> L <sup>-1</sup>	BOD mgO <sub>2</sub> L <sup>-1</sup>
I	23.90	40.39	8.16	4.89	1.53	18.70	40.35	8.14	9.95	4.44
II	23.50	40.51	8.17	4.67	2.29	18.40	40.49	8.12	8.42	1.98
III	23.90	39.92	8.18	5.51	3.21	18.50	39.90	8.15	8.42	6.58
IV	24.40	40.18	8.17	5.51	1.38	19	40.18	8.16	10.41	3.98
V	25.20	40.30	8.18	5.82	1.53	18.50	40.29	8.10	8.11	3.98
VI	24.10	40.23	8.15	4.44	1.53	18.70	40.20	8.08	8.87	2.44
VII	24.10	40.02	8.14	7.35	3.06	18.70	39.99	8.16	9.79	6.25
VIII	24	40.23	8.15	8.26	1.53	18.80	40.17	8.13	8.72	5.51
IX	22.10	40.51	8.32	6.36	4.67	18.10	40.45	8.30	7.59	2.91
X	22.80	40.61	8.20	7.56	4.44	17.70	40.58	8.16	8.42	2.91
XI	22.70	40.69	8.30	6.89	2.91	17.90	40.66	8.29	7.89	4.44
XII	22.30	40.71	8.33	7.18	5.20	17.90	40.67	8.32	8.32	3.67
XIII	23.40	40.81	8.29	9.18	5.97	18	40.78	8.25	10.71	6.73
VIX	22.60	40.82	8.31	5.59	4.44	17.90	40.80	8.29	7.85	5.20



**Fig. (2): Annual mean concentrations of physico-chemical parameters of water samples collected from the western sector of the Gulf of Suez.**

## 2. Nutrient salts

Tables (3 & 4) and Figure (3) showed the mean concentrations of nutrient salts ( $\mu\text{molL}^{-1}$ ) in water samples collected from the western sector of the Gulf of Suez. Nitrite fluctuated between the maximum mean values ( $2.82 \mu\text{molL}^{-1}$ ) recorded at St.V at El-Adabyia, this is may be attributed to increase human activities mainly from domestic drainage and shipping activities, while the minimum mean value ( $0.77 \mu\text{molL}^{-1}$ ) was recorded at St.II (El-Zaiytia). This is probably due to its instability; it is oxidized to nitrate or ammonia, by both chemical reaction and / or biological by bacteria (Barakat *et al.*, 2009). Also, nitrite values varied between the highest value ( $2.53 \mu\text{molL}^{-1}$ ) observed at St.VIX (Gemsa) and the lowest value ( $1.12 \mu\text{molL}^{-1}$ ) observed at St.XIII (Gebl El-Zeet). The maximum annual mean was recorded ( $2.31 \mu\text{molL}^{-1}$ ) at Gemsa, while the minimum value ( $1.48 \mu\text{molL}^{-1}$ ) was at Petroget. Also, the highest seasonal mean was recorded ( $2.51 \mu\text{molL}^{-1}$ ) during spring season and the minimum one ( $1.45 \mu\text{molL}^{-1}$ ) was during autumn season. This is may be to increased different human and shipping activities during warm season. This result agrees with that of Hamed *et al.* (2010).

The highest mean value of nitrate ( $67.88 \mu\text{molL}^{-1}$ ) was observed at St.III (El-Kabanon), this is may be due to disposal of treated and untreated sewage and industrial effluents. The lowest mean value ( $2.07 \mu\text{molL}^{-1}$ ) was observed at St.II (El-Zaiytia), this is probably attributed to increase in plankton biomass, which feed on such nutrient and cause depletion in its concentration. On the other sector, the maximum nitrate level ( $11.48 \mu\text{molL}^{-1}$ ) was recorded at St.VIX (Gemsa) and the minimum level ( $5.27 \mu\text{molL}^{-1}$ ) was at St.IX (El-Zafrana). The annual average values varied between ( $19.73-6.08 \mu\text{molL}^{-1}$ ) at El-Kabanon and Gebl El-Zeet. Seasonally, the mean values recorded between  $24.35$  and  $3.31 \mu\text{molL}^{-1}$  were during summer and autumn, respectively. Compared to the other results, the nitrate values recorded during this study were remarkable high. The variations of nitrate content in the north-western sector were affected by different factors, the discharge of waste water through different outfalls such as the new treatment of wastewater of Suez city, the concentration of dissolved oxygen, water temperature, mixing and aeration, uptake by phytoplankton, nitrification and denitrification as well as decomposition from bottom sediments.

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The mean values of  $\text{NH}_3\text{-N}$  content varied between the maximum value ( $43.15\mu\text{molL}^{-1}$ ) recorded at St.III (El-Kabanon) and the minimum value ( $3.24\mu\text{molL}^{-1}$ ) recorded at St.I (Port-tawfik). The maximum value may be indicator of the presence of pollutants of high activity and this is probably due to extensive discharge of different wastes. On the other hand, the mean values of  $\text{NH}_3\text{-N}$  ranged between the highest value ( $10.80\mu\text{molL}^{-1}$ ) was observed at St.XII (Ras Shoker), this is may be due to increased human and industrial activities. The lowest value ( $1.94\mu\text{molL}^{-1}$ ) was observed at St.IX (El-Zafrana). The annual means fluctuated between the highest value ( $23.98\mu\text{molL}^{-1}$ ) at El-Kabanon and the lowest value ( $4.31\mu\text{molL}^{-1}$ ) at Ras Bakr. On the other hand, the maximum seasonal mean ( $17.11\mu\text{molL}^{-1}$ ) was during spring, this is attributed to the high evaporation rate, increased sewage and shipping activities. The minimum mean recorded ( $3.99\mu\text{molL}^{-1}$ ) during autumn may be due to utilization and oxidation of ammonia by plankton cells, which phytoplankton flourishing and exhausted ammonia as nitrogen source.

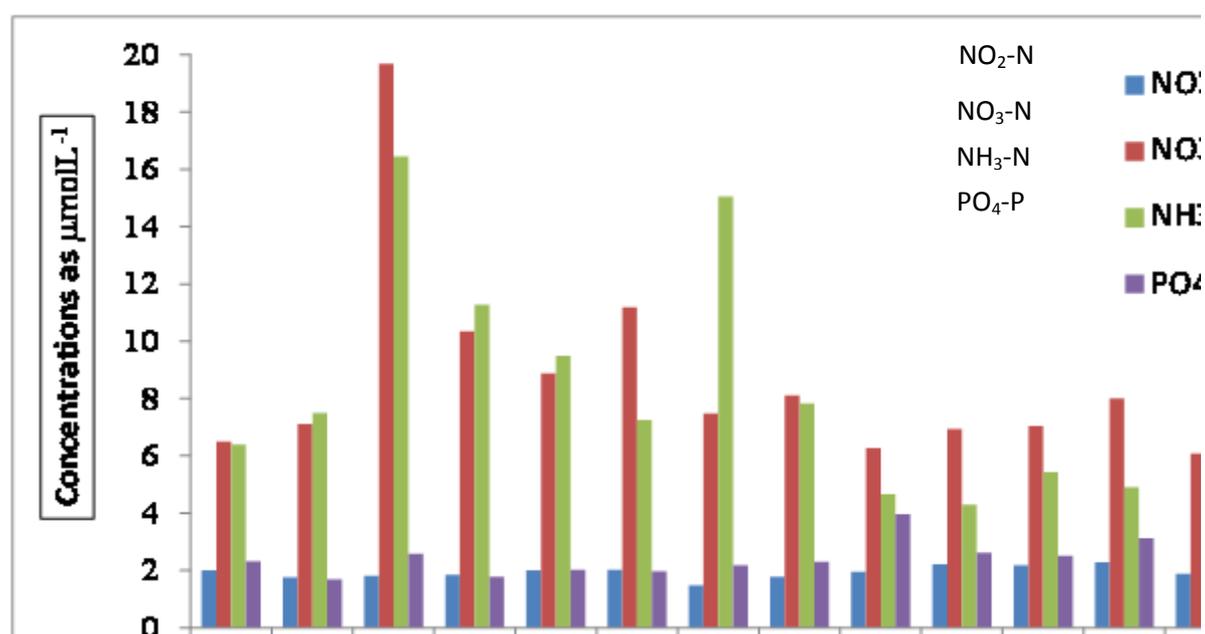
As shown in Tables (3 & 4), the  $\text{PO}_4\text{-P}$  mean levels ranged between the highest level ( $3.45\mu\text{molL}^{-1}$ ) was recorded at St.III (El-Kabanon), and the lowest level ( $0.93\mu\text{molL}^{-1}$ ) at St.VI (Green-Island) where this station is far away from pollution sources. Annually, the maximum mean ( $3.97\mu\text{molL}^{-1}$ ) was at El-Zafrana and the minimum ( $1.68\mu\text{molL}^{-1}$ ) was observed at St.VI (Green-Island). Seasonally, the maximum mean ( $3.88\mu\text{molL}^{-1}$ ) was during winter season, while the minimum mean ( $1.45\mu\text{molL}^{-1}$ ) was during summer season. This result agrees with the result of Hamed *et al.* (2010).

**Table (3): Mean concentrations of nutrient and phosphate salts ( $\mu\text{molL}^{-1}$ ) in water samples collected from the Western sector of the Gulf of Suez during spring and summer (2014).**

P. St.	Seasons							
	Spring (2014)				Summer (2014)			
	$\text{NO}_2\text{-N}$	$\text{NO}_3\text{-N}$	$\text{NH}_3\text{-N}$	$\text{PO}_4\text{-P}$	$\text{NO}_2\text{-N}$	$\text{NO}_3\text{-N}$	$\text{NH}_3\text{-N}$	$\text{PO}_4\text{-P}$
I	2.62	5.13	11.32	2.51	2.21	11.94	7.07	1.57
II	2.59	5.94	14.47	2.61	2.49	17.64	7.39	1.08
III	2.59	4.95	43.15	2.12	2.58	67.88	40.72	2.07
IV	2.51	8.51	15.93	2.21	2	24.84	16.42	1.72
V	2.82	7.65	16.31	2.31	1.56	20.79	11.13	2.07
VI	2.44	18.09	10.91	2.31	2.18	20.79	4.21	0.93
VII	2.09	6.98	13.02	2.36	0.97	14.89	4.21	1.03
VII	2.38	5.22	11.88	2.22	0.79	16.25	5.35	1.13
IX	1.78	6.62	2.97	4.77	2.22	5.27	4.27	2.02
X	2.09	7.25	4.37	2.95	2.20	5.81	5.83	1.87
XI	2.11	6.71	5.67	2.51	2.42	6.62	4.59	1.97
XII	2.31	7.83	4.97	3.54	2.24	6.93	10.80	2.07
XIII	2.22	5.40	6.26	3.09	2.31	5.27	8.26	2.22
XIV	2.53	7.88	4.12	4.77	2.29	10.98	4.24	1.88

**Table (4):** Mean concentrations of nutrient and phosphate salts ( $\mu\text{molL}^{-1}$ ) in water samples collected from the Western sector of the Gulf of Suez during autumn (2014) and winter (2015).

P. St.	Seasons							
	Autumn (2014)				Winter (2015)			
	NO <sub>2</sub> -N	NO <sub>3</sub> -N	NH <sub>3</sub> -N	PO <sub>4</sub> -P	NO <sub>2</sub> -N	NO <sub>3</sub> -N	NH <sub>3</sub> -N	PO <sub>4</sub> -P
I	1.32	4.23	3.42	2.41	1.89	4.77	4.11	2.81
II	0.77	2.07	3.46	0.99	1.21	2.66	4.65	2.16
III	0.78	2.47	5.73	2.71	1.26	3.60	6.32	3.45
IV	1.34	3.78	6.75	1.38	1.58	4.23	5.99	1.82
V	1.87	3.38	4.38	1.82	1.81	3.38	6.16	1.92
VI	1.87	2.75	6.27	2.17	1.61	3.15	7.67	2.46
VII	1.65	3.38	6.75	2.22	1.21	4.68	6.10	3.15
VIII	2	4.23	7.83	2.31	2.03	6.75	6.26	3.40
IX	1.72	7.56	1.94	4.38	2.11	6.63	2.92	4.72
X	2.27	9.14	2.97	2.41	2.38	5.58	4.05	3.29
XI	2.16	8.37	5.45	2.17	2.09	6.84	6.05	3.39
XII	2.20	10.22	4.59	2.94	2.44	7.07	5.78	3.94
XIII	1.12	7.61	5.67	2.41	1.87	6.03	6.18	3.39
XIV	2.14	9.45	3.35	4.33	2.27	11.48	4.54	4.53



**Fig. (3):** Annual mean concentrations of nutrient and phosphate salts ( $\mu\text{molL}^{-1}$ ) of water samples collected from the western sector of the Gulf of Suez.

The calculated ratios for N:P are given in Table (5) for the northwestern and Table (6) for the southwestern sectors of the Gulf are more than that of Redfield ratio N:P = 16:1 (Redfield *et al.*, 1963). Thus, phosphorus is the limiting factor for phytoplankton growth in the study area. The level of nutrient salts indicated that the northwestern sector of Suez gulf is in the eutrophic state according to the standard levels reported by Franco (1983) (Table 8).

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**Table (5): Ranges, seasonal means, annual means and N:P ratio of nutrient salts of water samples collected from the northwestern sector of the study area during (2014-2015).**

Parameter	Seasons					
	Values	Spring (2014)	Summer (2014)	Autumn (2014)	Winter (2015)	Annual mean
Nitrite ( $\mu\text{molL}^{-1}$ )	Ranges	2.01-2.87	0.70-2.61	0.74-2.03	1.18-2.07	0.70-2.87
	Seasonal mean	2.51	1.85	1.45	1.58	1.85
Nitrate ( $\mu\text{molL}^{-1}$ )	Ranges	4.80-18.1	11.89-67.94	2.21-4.26	2.62-6.79	2.21-18.1
	Seasonal mean	7.81	24.35	3.31	4.19	9.89
Ammonia ( $\mu\text{molL}^{-1}$ )	Ranges	10.84-43.21	4.17-4.77	3.20-7.88	4.05-7.71	3.20-43.21
	Seasonal mean	17.11	12.06	5.55	5.91	10.16
phosphate ( $\mu\text{molL}^{-1}$ )	Ranges	2.06-2.67	0.84-2.35	0.83-2.47	1.79-3.59	0.83-3.59
	Seasonal mean	2.33	1.45	1.99	2.66	2.11
N:P ratios		11.77	26.39	5.18	4.39	10.38

**Table (6): Ranges, seasonal means, annual means and N:P ratio of nutrient salts of water samples collected from the southwestern sector of the study area during (2014-2015).**

Parameter	Seasons					
	Values	Spring (2014)	Summer (2014)	Autumn (2014)	Winter (2015)	Annual mean
Nitrite ( $\mu\text{molL}^{-1}$ )	Ranges	1.72-2.57	2.18-2.46	1.09-2.33	1.80-2.51	1.09-2.57
	Seasonal mean	2.17	2.28	1.93	2.19	2.14
Nitrate ( $\mu\text{molL}^{-1}$ )	Ranges	5.34-7.95	5.21-11.07	7.50-10.29	5.51-11.55	5.21-11.55
	Seasonal mean	7.04	8.72	6.81	6.95	7.38
Ammonia ( $\mu\text{molL}^{-1}$ )	Ranges	2.91-6.29	4.19-11.08	1.82-5.73	2.39-6.23	1.82-11.08
	Seasonal mean	4.73	7.17	3.99	5.03	5.23
phosphate ( $\mu\text{molL}^{-1}$ )	Ranges	2.38-5.01	1.77-2.29	2.12-4.50	3.27-4.70	1.77-4.70
	Seasonal mean	3.61	2.0	3.11	3.88	3.15
N:P ratios		3.86	9.09	4.09	3.65	4.68

The correlation coefficient between water characteristics in water samples collected from the Western sector of the Gulf during (2014-2015) was shown in Table (7).

**Table (7): Correlation coefficient between water characteristics in water samples collected from the Western sector of the Gulf during (2014-2015).**

	T C°	S ‰	pH	DO	BOD	NO <sub>2</sub> -N	NO <sub>3</sub> -N	NH <sub>3</sub> -N	PO <sub>4</sub> -P
T C°	1								
S ‰	0.12205	1							
Ph	0.45667	0.592302	1						
DO	-0.7365	-0.08948	-0.37912	1					
BOD	-0.3043	-0.25869	-0.0431	0.404499	1				
NO <sub>2</sub> -N	0.15010	0.309375	0.329474	-0.09073	-0.04991	1			
NO <sub>3</sub> -N	0.38093	-0.15794	0.313646	-0.31493	0.171698	0.208268	1		
NH <sub>3</sub> -N	0.17253	-0.43111	0.016666	-0.16588	0.336865	0.360441	0.541559	1	
PO <sub>4</sub> -P	-0.4474	0.306393	0.282522	0.335418	0.218523	0.19526	-0.17712	-0.20557	1

The present results matched with the results stated by Hamed and Said (2000) and Fahmy *et al.* (2005) who reported that the coast of northwestern sector of the Gulf of Suez (Suez Bay) is richer in nutrient salts followed in decreasing order to southwestern sector of the Gulf, due to the intense discharge of industrial and domestic wastes in waters of the northwestern sector. As shown in Table (8), the results of physico-chemical parameters are agreed with other findings by Hamed *et al.* (2010) at the northern Red Sea (Suez Bay) and Soliman *et al.* (2015) at Suez Canal. Moreover, the results of nutrient salts are higher than the results found by Abdelmomy and El-Moselhy (2015) and Nassar *et al.* (2016) at the northern Red Sea, also Soliman *et al.* (2015) at Suez Canal (except for nitrite).

**Table (8): Comparison between levels of physico-chemical parameters and nutrient and phosphate salts in the present study with those of neighboring regions.**

Parameter Area	Temp. °C	S‰	PH	DO mgO <sub>2</sub> L <sup>-1</sup>	BOD mgO <sub>2</sub> L <sup>-1</sup>	NO <sub>2</sub> -N µmolL <sup>-1</sup>	NO <sub>3</sub> -N µmolL <sup>-1</sup>	NH <sub>3</sub> -N µmolL <sup>-1</sup>	PO <sub>4</sub> -N µmolL <sup>-1</sup>	Reference
Northwestern sector of the Gulf	18.40-30.10	39.90-40.51	8.08-8.39	4.28-10.41	1.53-7.04	0.77-2.82	2.07-67.88	3.24-43.15	0.93-3.59	Present study
Southwestern sector of the Gulf	17.70-33.30	40.45-40.88	8.16-8.37	4.36-10.71	1.53-6.73	1.12-2.53	5.27-11.48	1.94-10.80	1.87-4.77	
Northwestern sector of the Gulf	19.0-28.0	41.02-42.30	8.06-8.36	8.20-10.95	-	0.70-4.95	4.64-20.85	3.12-16.70	0.32-3.04	
Gulf of Suez	-	42.10-43.27	7.62-7.65	1.94-2.87	151-250	0-0.188	0.01-8.02	-	15.0-61.0	Emara <i>et al.</i> , 2013
Suez Canal	14.89-29.24	29.85-44.99	7.51-8.18	5.56-10.72	1.36-7.95	0.05-16.83	1.04-25.33	0.26-22.12	0.03-2.11	Soliman <i>et al.</i> , 2015
Gulf of Suez	19.10-31.20	39.70-41.70	7.60-8.44	-	-	-	-	-	-	El-Metwally, 2015
Northern Red Sea	17.96-32.56	40.02-42.32	7.78-8.21	6.05-8.05	0.73-4.15	0.07-0.12	0.43-3.17	2.41-12.56	0.08-0.38	Abdelmomy and El-Moselhy, 2015
Northern Red Sea	16.50-27.50	-	7.75-8.27	3.35-10.39	-	0.028-0.408	0.170-1.205	0.067-1.248	0.007-0.413	Nassar <i>et al.</i> , 2016
Oligotrophic level							0.51	0.51	0.05	Skrivanic and Strin, 1982
Eutrophic level							4.02	2.02	0.3	Franco, 1983

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### Conclusion

Water characteristics of the Gulf of Suez show constant seasonal and local trends over the year; this is attributed to the effect of different water flows from the Red Sea and Suez Canal. Also, the Gulf of Suez suffered from different considerable source of land based and sea based activities; waste discharging from shipping transit, untreated domestic sewage from Suez City and other tourist villages, oil and industrial effluents from refineries and petro-chemical companies and fish processing activities. These sources are concentrated in the northern part of the Gulf. The southern part of the Gulf is affected mainly by seepage from oil fields, effluents from oil rigs, waste discharging from tankers passing through the Gulf of Suez and different fishing activities.

The present results indicated that the following:

1. The maximum concentration of nutrient salts was recorded in northwestern sector, this is due to waste discharging from shipping transit, untreated domestic sewage from Suez City and other tourist villages, oil and industrial effluents from refineries and petro-chemical companies and fish processing activities.
2. the area of investigation can be divided into two regions Suez Bay region as an eutrophic water (high productivity) and the part of the Gulf as going southward to Gemsa, which has considered as oligotrophic water (low productivity).
3. the maximum N:P ratio (26.39) was recorded during summer at the northwestern sector of the Gulf.
4. the maximum seasonal values of nutrient salts was recorded in spring and summer season, this is attributed to increase human and shipping activities and extensive discharge of treated and untreated sewage.

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**المياه في الجانب الغربي لخليج السويس (البحر الأحمر) خلال عامي 2015/2014**

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تم تعيين الخصائص الكيميائية والفيزيائية والأملاح المغذية موسمياً في عينات المياه المجمعته من 14 محطة على الجانب الغربي لخليج السويس بداية من ربيع 2014 حتى شتاء 2015. أظهرت النتائج أن المتوسط السنوي لعينات المياه السطحية المجمعته من الجانب الشمالي الغربي لخليج السويس لكل من درجة الحرارة، درجة الملوحة، الأس الهيدروجيني، الأكسجين الذائب، الأكسجين المستهلك حيويًا، النترات، النيتريت، الأمونيا و الفوسفات (30.10-18.40 درجة مئوية، 39.90-40.51%، 8.08-8.39، 4.28-10.41 مجم أكسجين/لتر، 1.53-7.04 مجم أكسجين/لتر، 0.77-2.82 ميكرومول/لتر، 2.07-67.88 ميكرومول/لتر، 3.24-43.15 ميكرومول/لتر و 0.93-3.45 ميكرومول/لتر على التوالي. وقد كانت قيم هذه القياسات على التوالي لعينات المياه السطحية المجمعته من الجانب الجنوبي الغربي لخليج السويس مساوية (33.30-17.70 درجة مئوية، 40.45-40.88%، 8.16-8.37، 4.36-10.71 مجم أكسجين/لتر، 1.53-6.73 مجم أكسجين/لتر، 1.12-2.53 ميكرومول/لتر، 5.27-11.48 ميكرومول/لتر، -1.94-10.80 ميكرومول/لتر و 1.87-4.77 ميكرومول/لتر).

و بصفة عامة تشير النتائج الى أن تركيز هذه المتغيرات تكون عالية نسبياً وخصوصاً (الأملاح المغذية) في الجزء الشمالي الغربي لخليج السويس وتقل تدريجياً في الاتجاه الجنوبي (البحر الأحمر). وربما يرجع ذلك الى زيادة الصرف الصحي والصناعي الملقى في الناحية الشمالية الغربية لخليج السويس. كما أوضحت النتائج ارتفاع معدل الأملاح المغذية في موسمي الربيع والصيف وربما يرجع ذلك لزيادة الأنشطة البشرية والصناعية والصرف الصحي المعالج وغير المعالج الملقى ونقصها في موسم الخريف. كما أوضحت النتائج أن نسبة النيتروجين الى الفسفور كانت 10.83 في عينات المياه المجمعته من الجانب الشمالي الغربي، بينما سجلت 4.68 في عينات المياه المجمعته من الجانب الجنوبي الغربي ويدل هذا على أن المنطقة الشمالية الغربية ذاتية التغذية وهذا يدل على ما تعانيه المنطقه من زيادة الصرف الصحي الملقى والمخلفات الصناعية.