

Levels of silicate, the major nutrient for diatoms, in three Mediterranean coastal basins subjected to different pollution sources

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Abstract

The seasonal variations of silicate were investigated in the surface and bottom waters of three Mediterranean coastal areas to reflect the silicate sources and availability and consequently the biomass of diatoms inhabiting these marine basins subjected to different land based sources of pollution. The study areas are; Mex Bay, a semicircular basin west of Alexandria, has a mean depth of 9.8 m and receives several untreated effluents (agricultural, industrial and domestic wastes). The region in front of the Eastern Harbor (EH) of Alexandria has a maximum depth of 22 m with no distinct boundaries and receives only untreated domestic wastes. Abu-Kir Bay, a semi-enclosed basin east of Alexandria, has an average depth of 12 m and receives untreated industrial and domestic wastes from > 30 factories. The order of silicate abundance was: Mex Bay > Abu Kir Bay > in front of EH. This coincided with different industrial operations in Mex and Abu Kir regions, beside the continuous discharges of variable amounts of silicate enriched brackish waters in both bays and the effect of domestic wastes only on the area in front of EH. Accordingly, the allochthonous silicate sources dominated the autochthonous sources, resulting from decomposition of siliceous matter, as confirmed from the considerable silicate decrease with depth and with distance from land based sources of pollution. The present results are considered as data base for studying the distribution of diatoms, the dominant phytoplankton group.

Key words: Mediterranean basins, pollution, silicate, sources, diatoms.

INTRODUCTION

The coastal waters of Alexandria have been subjected during the last four decades to extensive discharges of untreated domestic, industrial and agricultural wastes. The industrial activities in Alexandria, the second largest city in Egypt, constitute 40% of the total Egyptian industry. According to Said and Maiyza [1], 183×10^6 m³ of untreated domestic sewage and wastewaters are discharged annually from land-based sources into the coastal waters of Alexandria. This figure is liable to an increase with progress of time following the continuous increase in population. Anthropogenic nutrient inputs play an important role in the high productivity and biomass of the coastal zone of Alexandria relative to its continental shelf [2]. The data obtained from previous studies showed that these waters were suffering from risks of deterioration, as a result of increase in degradation of the coastal water quality [3,4,5,6]. This work, a part of the MED-POL Program (Phase II), was carried out to investigate the regional and seasonal distribution of silicate in three Mediterranean coastal regions in front of Alexandria, subjected to different pollution sources.

The estimation of the present levels of reactive silicon delivered to the study areas via man's impact is a tool to evaluate the role of land-based sources as major contributors of pollutants to these areas. The results of this study are considered as data base for investigating the regional and seasonal distribution of diatoms, the dominant group of phytoplankton.

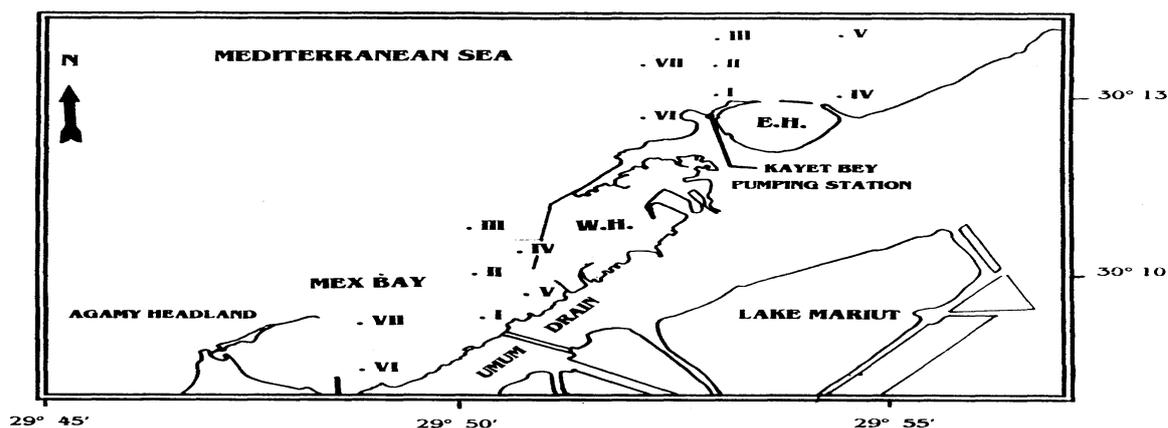


Figure 1: A map showing the sampling stations in Mex Bay and the area in front of the Eastern Harbor.

STUDY AREA

Mex Bay, a semicircular basin west of Alexandria (Fig. 1), has a mean depth, area and volume of 9.8 m, 19.4 km² and 190.3×10^6 m³ [7]. It receives several agricultural, industrial and domestic wastes, mainly from land-based sources; 1) brackish water from Umum Drain (UD), discharging 6×10^6 m³ d⁻¹ agricultural drainage waters contaminated with domestic and industrial wastes; 2) Misr Chemicals Company

(MCC) effluent, discharging $0.035 \times 10^6 \text{ m}^3 \text{ d}^{-1}$ of untreated industrial wastes into the bay; and 3) Noubaria Canal discharging $0.09 \times 10^6 \text{ m}^3 \text{ d}^{-1}$ in addition to $0.002 \times 10^6 \text{ m}^3$ /day of wastes from Tanneries and slaughterhouse. Following these discharges, Mex Bay became characterized by two water layers; an upper brackish water and a lower saline water layer [8].

The coastal Mediterranean region in front of the Eastern Harbor (EH) of Alexandria has no distinct boundaries (Fig. 1). The water of this area, with a maximum depth of 22 m, is subjected to exchanges with the open coastal seawater of Alexandria and with the EH throughout the two harbor's outlets (El-Boughaz and El-Silselah). This area receives from $0.15 - 0.20 \times 10^6 \text{ m}^3 \text{ d}^{-1}$ untreated domestic wastes throughout the main sewage tube at Kayet Bay Fort.

Abu-Qir Bay is a semi-enclosed basin located at 36 km east of Alexandria (Fig.2). This bay has an average depth, area and volume of 12 m, 360 km^2 and 4.32 km^3 [9]. In the western investigated region of this bay, the maximum and average depths were 9 and 3.8 m. The exchange of water between Abu-Qir Bay and Lake Edku in the south, occurring through El-Maadia Channel, is controlled by the difference in water levels between the bay and the lake and by the prevailing wind. Mohamed [10] illustrated that the monthly current measurements in this channel showed a predominant lake-bay flow all the year round. In the heavily polluted southwestern area of Abu-Qir Bay, 1.5 to $2.0 \times 10^6 \text{ m}^3 \text{ d}^{-1}$ of untreated industrial and domestic wastewaters from > 30 factories were pumped via Tabia Pumping Station (TPS), receiving these wastes from Abu-Qir Bay Drain (Fig. 3). The surface salinity distribution in the bay during the high flow period (summer) showed low salinity values reaching less than 4 ‰ at the lake-bay connection. However, during the low flow period (winter), the salinity values were more than 22‰ [9]. The water exchange between Abu-Qir Bay and the open sea is summarized in a surface bay-sea current of salinity 36‰ encountered by a bottom sea-bay current of salinity 39.1‰.

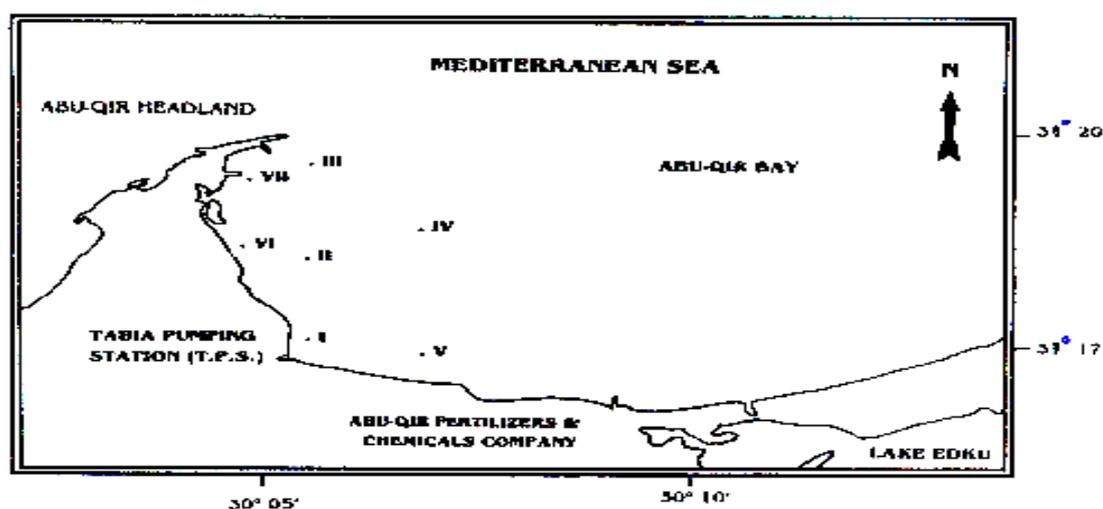


Figure 2: Map of Abu-Qir Bay, showing position of stations.

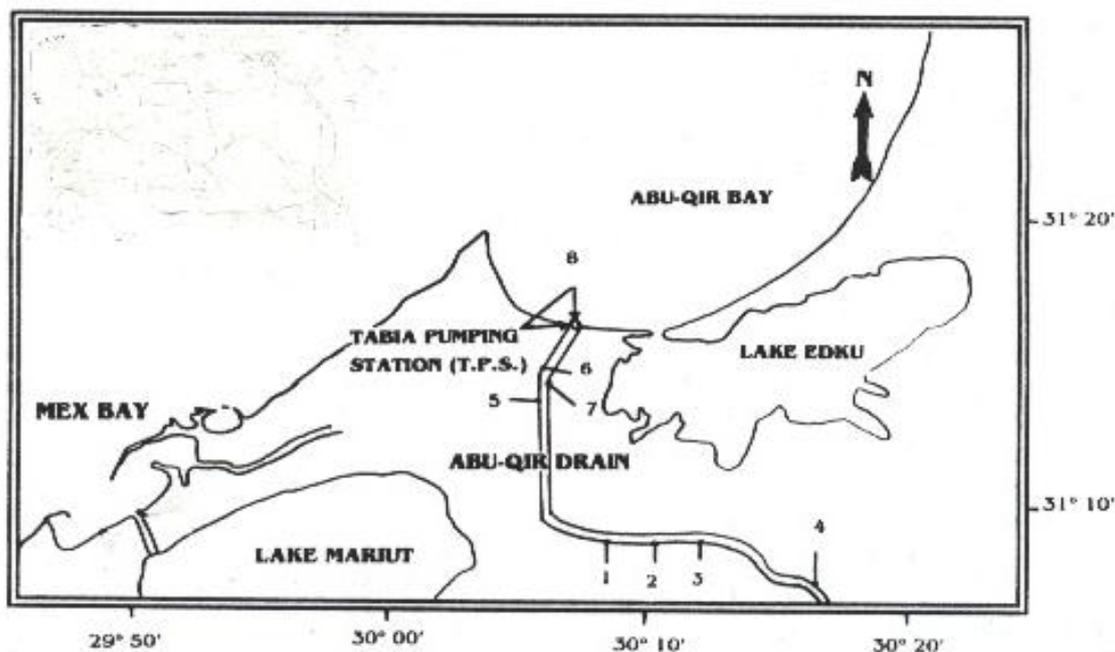


Figure 3: Land-based sources of pollution in Abu-Qir region.

MATERIAL AND METHODS

Surface and bottom water samples were collected seasonally during April 1991 to January 1992 from the study areas along transects perpendicular to the coastline. According to the maximum depth, from 2 to 3 stations were sampled along each transect (Figs.1 and 2). The surface samples were collected using a silicon / teflon manual water pump at 30 cm below the water surface to avoid floating matter. The bottom samples were collected by a 5 liters PVC Niskin water sampler at 30 cm above the sea bottom to avoid disturbance of sediments. Water samples were also collected from the effluents in Mex and Abu-Qir regions, as well as from the TPS effluent from July 1991 to April 1992, using a plastic bucket. The water samples were kept in acid-cleaned PET bottles, as described by Pai et al., [11]. Immediately before sampling, the bottles were rinsed with a portion of the seawater samples. Silicate was determined spectrophotometrically according to Strickland and Parsons [12] in filtered samples using Millipore membrane filter papers (0.45 μm porosity, 47 mm diameter).

Table 1: The absolute values, regional and seasonal averages of silicate (μM) in the surface and bottom waters of Mex Bay.

	Months	April	July	October	January	Regional		
Stations	Depths		1991		1992	averages	\pm	SD
I	S	81.40	18.50	43.80	21.20	41.23	\pm	25.19
	B	9.54	18.50	26.60	1.20	13.96	\pm	9.52
II	S	95.70	21.10	68.10	26.90	52.95	\pm	30.62
	B	5.67	20.70	5.90	1.60	8.47	\pm	7.27
III	S	62.40	22.90	47.10	3.90	34.08	\pm	22.40
	B	5.29	3.02	1.60	1.20	2.78	\pm	1.60
IV	S	72.50	17.20	2.50	14.90	26.78	\pm	26.98
	B	5.29	17.00	3.90	0.90	6.77	\pm	6.11
V	S	66.70	13.90	3.90	21.80	26.58	\pm	24.02
	B	6.14	12.10	3.00	1.30	5.64	\pm	4.12
VI	S	126.80	25.40	3.00	32.60	46.95	\pm	47.38
	B	21.20	29.00	24.00	2.90	19.28	\pm	9.86
VII	S	116.50	24.70	24.00	35.80	50.25	\pm	38.53
	B	5.39	22.90	28.80	1.40	14.62	\pm	11.51
Seasonal	S	88.86	20.53	27.49	22.44	39.83	\pm	28.42
	\pm SD	23.19	3.90	24.18	10.03			
averages	B	8.36	17.60	13.40	1.50	10.22	\pm	6.00
	\pm SD	5.43	7.67	11.45	0.60			

RESULTS

Mex Bay

The absolute surface and bottom concentrations of reactive silicate in Mex Bay, as well as their regional and seasonal averages are listed in Table 1. The surface absolute values ranged very widely from 2.5 μM at station IV in October to 126.8 μM at station VI in April. The bottom absolute concentration varied from 0.9 μM at station IV in January to 29.00 μM at station VI in July. The surface water at station II exhibited the maximum regional average value of 52.95 \pm 30.62 μM , while the minimum average of 26.58 \pm 24.02 μM was recorded at station V. The difference between the bottom regional averages was noticeable, ranging significantly from 2.78 \pm 1.60 μM at station III to 19.28 \pm 9.86 μM at station VI. The minimum and maximum surface seasonal averages appeared in July (20.53 \pm 3.90 μM) and April (88.86 \pm 23.19 μM). However, the bottom water showed a lowest seasonal average of 1.50 \pm 0.60 μM in January and a peak of 17.60 \pm 7.67 μM in July. The surface annual mean concentration of 39.83 \pm 28.42 μM was approximately four times higher than that for the bottom mean (10.22 \pm 6.00 μM).

In front of the Eastern Harbor (EH)

The surface and bottom absolute concentrations of silicate in front of the EH, as well as their regional and seasonal averages are given in Table 2. The surface waters at stations II and VI in July exhibited the minimum absolute concentration of $0.19 \mu\text{M}$, whereas the surface maximum absolute value ($38.80 \mu\text{M}$) was recorded at station II in October. For the bottom water, station I showed the highest absolute value in April ($19.40 \mu\text{M}$) and station III recorded the minimum absolute value of ($0.10 \mu\text{M}$) in January. The surface regional average values ranged from $2.63 \pm 2.62 \mu\text{M}$ at station V to $14.67 \pm 16.0 \mu\text{M}$ at station II. The bottom averages varied from $2.03 \pm 2.03 \mu\text{M}$ at station III to $5.37 \pm 8.11 \mu\text{M}$ at station I. The highest surface ($18.79 \pm 9.05 \mu\text{M}$) and bottom seasonal averages ($8.80 \pm 4.56 \mu\text{M}$) appeared in April. However, the lowest seasonal averages were 0.66 ± 0.88 (surface) and 0.30 ± 0.17 (bottom) in January. The surface annual mean concentration ($8.84 \pm 8.21 \mu\text{M}$) was approximately triple that for the bottom mean ($3.23 \pm 3.33 \mu\text{M}$).

Table 2: The absolute values, regional and seasonal averages of silicate (μM) in the surface and bottom waters in front of the Eastern Harbor of Alexandria.

	Months	April	July	October	January	Regional		
Stations	Depths		1991		1992	averages	\pm	SD
I	S	19.70	1.70	7.50	0.40	7.33	\pm	7.63
	B	19.40	0.76	1.10	0.20	5.37	\pm	8.11
II	S	19.50	0.19	38.80	0.20	14.67	\pm	16.00
	B	5.90	1.89	1.40	0.30	2.37	\pm	2.12
III	S	13.10	0.66	22.30	0.20	9.07	\pm	9.23
	B	5.40	1.70	0.90	0.10	2.03	\pm	2.03
IV	S	9.60	0.66	14.80	2.80	6.97	\pm	5.60
	B	7.30	0.66	0.80	0.60	2.34	\pm	2.86
V	S	7.10	1.70	1.20	0.50	2.63	\pm	2.62
	B	9.80	0.76	0.80	0.50	2.97	\pm	3.95
VI	S	33.20	0.19	1.90	0.30	8.90	\pm	14.05
	B	8.10	1.30	11.60	0.20	5.30	\pm	4.73
VII	S	29.30	0.60	19.20	0.20	12.33	\pm	12.45
	B	5.70	0.28	3.70	0.20	2.47	\pm	2.34
Seasonal	S	18.79	0.81	15.10	0.66	8.84	\pm	8.21
	\pm SD	9.05	0.59	12.28	0.88			
averages	B	8.80	1.05	2.90	0.30	3.26	\pm	3.33
	\pm SD	4.56	0.55	3.68	0.17			

Abu-Qir Bay

The surface and bottom absolute concentrations of silicate in Abu-Qir Bay, as well as their regional and seasonal averages are shown in Table 3. Abu-Qir Fertilizers and

Chemicals Company effluents increased the absolute surface concentration at station V in July to 83.5 μM . This maximum was lowered to 2.60 μM at station VII in January. In the bottom water, the absolute values ranged very significantly in October from 1.10 μM at station III to 86.70 μM at station I. The maximum surface regional average value of $35.28 \pm 28.37 \mu\text{M}$ appeared at station V and the minimum surface regional average of $19.76 \pm 21.98 \mu\text{M}$ (C.V. = 111%) was calculated at station II. The bottom regional averages varied significantly from 5.30 ± 1.45 and $5.30 \pm 3.65 \mu\text{M}$ at stations II and III, respectively to $35.73 \pm 19.04 \mu\text{M}$ at station V. The peak of surface seasonal average value was found in October ($54.69 \pm 22.53 \mu\text{M}$) and the minimum surface seasonal average appeared in April ($8.39 \pm 4.27 \mu\text{M}$). The bottom seasonal averages ranged markedly from $3.93 \pm 1.9 \mu\text{M}$ in January to $35.73 \pm 32.79 \mu\text{M}$ in October. The surface annual mean concentration ($24.03 \pm 18.58 \mu\text{M}$) was higher than that of $18.13 \pm 11.47 \mu\text{M}$ for the bottom mean.

Table 3: The absolute values, regional and seasonal averages of silicate (μM) in the surface and bottom waters of Abu-Qir Bay.

	Months	April	July	October	January	Regional		
Stations	Depths		1991		1992	averages	\pm	SD
I	S	12.20	22.60	21.60	35.40	22.95	\pm	8.25
	B	8.68	24.60	86.70	4.60	31.15	\pm	32.93
II	S	8.14	9.10	57.70	4.10	19.76	\pm	21.98
	B	5.88	6.20	6.30	2.80	5.30	\pm	1.45
III	S	4.07	7.10	74.70	4.30	22.54	\pm	30.14
	B	7.50	10.10	1.10	2.50	5.30	\pm	3.65
IV	S	8.59	26.80	42.80	7.30	21.37	\pm	14.58
	B	6.69	9.26	18.40	2.70	9.26	\pm	5.77
V	S	16.50	83.50	27.90	13.20	35.28	\pm	28.37
	B	53.30	53.40	28.30	7.90	35.73	\pm	19.04
VI	S	4.70	5.29	78.20	3.40	22.90	\pm	31.94
VII	S	4.52	6.71	79.90	2.60	23.43	\pm	32.63
	B	3.79	7.75	73.60	3.10	22.06	\pm	29.81
Seasonal	S	8.39	23.01	54.69	10.04	24.03	\pm	18.58
	\pm SD	4.27	25.91	22.53	10.88			
Averages	B	14.31	18.55	35.73	3.93	18.13	\pm	11.47
	\pm SD	17.50	16.72	32.79	1.90			

Land-based sources (LBS)

In Abu-Qir region, the absolute concentrations and the regional averages of silicate in the seven additional main effluents (BDC, MRC, DCC, WTC, MC, QFC and RPC) discharging into Abu-Qir Drain, which opens into TPS are listed in Table 4. In July, the minimum absolute value of 116.90 μM appeared in the MRC effluent and the

maximum absolute concentration (278.90 μM) was recorded in the RPC effluent. This effluent also exhibited the maximum absolute values of 49.10, 130.50 and 2.71 μM in October, January and April, respectively. Accordingly, this effluent showed the highest regional average value of $115.30 \pm 104.95 \mu\text{M}$, whereas the minimum of $35.51 \pm 47.20 \mu\text{M}$ was calculated for the MRC effluent. In the other effluents in Abu-Qir region, the concentrations varied from 6.90 μM in the DFC effluent to 23.50 μM in the MC effluent in October, from 9.80 μM in the BDC effluent to 25.50 μM in the QFC effluent in January and from 0.67 μM in the BDC effluent to 2.36 μM in the QFC effluent in April. According to these figures, the concentrations varied very widely in TPS, receiving all these seven effluent discharges, from 3.21 μM in April to 355.50 μM in July, giving an average of $105.83 \pm 144.83 \mu\text{M}$, which was greatly affected by the RPC effluent.

In Mex region, an extraordinary high absolute value was recorded in July in the MCC effluent (323.20 μM) and was extremely lowered to a minimum of 0.60 μM in January. As a result, the regional average value for this effluent ($89.56 \pm 135.29 \mu\text{M}$) showed a C.V. value of 151%. Similarly, the high C.V. of 109% calculated for the regional average value of $3.04 \pm 68.98 \mu\text{M}$ for UD resulted from the very low 4.06 μM and very high 180.20 μM absolute values in this drain in April and July, respectively.

Table 4: The absolute values and the regional averages of silicate (μM) in the effluents of land-based sources of pollution

	July	October	January	April	Regional	\pm	SD
Effluents		1991		1992	averages		
1	133.30	22.60	9.80	0.67	41.59	\pm	53.52
2	116.90	12.70	11.30	1.13	35.51	\pm	47.20
3	143.80	10.20	20.50	0.95	43.86	\pm	58.11
4	156.90	8.00	15.90	1.32	45.53	\pm	64.51
5	175.80	23.50	12.90	1.23	53.36	\pm	71.13
6	212.20	6.90	25.50	2.36	61.74	\pm	87.30
7	278.90	49.10	130.50	2.71	115.30	\pm	104.95
8	355.50	21.60	43.00	3.21	105.83	\pm	144.83
9	323.20	28.20	0.60	6.24	89.56	\pm	135.29
10	180.20	25.70	42.20	4.06	63.04	\pm	68.98

- 1) BDC : Bida Dyes Company 2) MRC : Misr Rayon Company
 3) DCC : Dyes & Chemicals Company 4) WTC : Weaving & Textile Company
 5) MC : Montazah Canal 6) QFC : Qaha Food Company
 7) RPC : Rakta Paper Company 8) TPS : Tabia Pumping Station
 9) MCC : Misr Chemicals Company
 10) UD : Umum Drain

DISCUSSION

The importance of silicate is concentrated in being the major nutrient for diatoms, the dominant phytoplankton group. Before three decades, Paasche [13] stated that the growth of these plants in natural waters was regulated by the availability of silica in the dissolved state. It is well known that diatom production can be temporally limited by a lack of silicate and stimulated by a new supply of silicate. Silicate in natural waters is derived from two major sources; 1) allochthonous, introduced to the aquatic environments by water discharges through running water systems, as well as by the effluents of different land-based sources. These external sources can control the regional and to some extent the seasonal variations of silicate in the marine environment; 2) autochthonous, which depends upon regeneration of silicon from decomposition of the siliceous matter. The release of unaltered diatom frustules eaten by aquatic organisms in the food chain leads to redissolution of a portion of this particulate silicon. Some of the siliceous remains probably will enter the sediments and are further included in regeneration processes. Adsorption of silicate on suspended matter and its subsequent precipitation act as an important pathway of silicate removal from the water column. Liss and Spencer [14] stated earlier that 10-20% of silicate entering the oceans was removed by this process. Generally speaking, the surface silicate levels were higher in Mex Bay, due to the intensive industrial operations taking place in the Mex region, beside the continuous discharges of huge amounts of agricultural run-off from UD, compared with the conditions in Abu-Qir Bay and in front of the EH.

Mex Bay

In Mex Bay, the surface regional average silicate values showed their maximum ($52.95 \pm 30.62 \mu\text{M}$) at station II, located in the middle of the transect opposite to UD (Fig. 1). The surface waters at stations VI and VII, selected along the transect opposite to chlor-alkali plant (Fig. 1), also showed high regional averages of 46.95 ± 47.38 and $50.25 \pm 38.53 \mu\text{M}$, respectively (Table I). These surface averages indicate the role of land-based sources of pollution, which probably introduced large amounts of silicate to Mex Bay. On the other hand, the maximum regional average silicate value for the bottom water ($19.28 \pm 9.86 \mu\text{M}$) was obtained at station VI (Table I). The regression equation of silicate against ‰; $\text{silicate } (\mu\text{M}) = 10.318 + 1.547 \text{ ‰}$ for the surface water, indicates that if ‰ = 0.00 (almost freshwater), the silicate concentration at station I, located opposite to UD (Fig. 1) would be $10.318 \mu\text{M}$. Nevertheless, the regional average silicate concentration at this station ($41.23 \mu\text{M}$), as shown from Table I, indicates that UD might not be the main source of silicate into Mex Bay. During mixing process, silicate might be partially removed from solution. The statistically significant negative correlation between surface silicate with pH ($r = -0.571$, $P < 0.001$) and with TSM ($r = -0.493$, $P < 0.001$) and its significant positive correlation with NH_4 ($r = 0.734$, $P < 0.001$), as well as the positive correlations between bottom silicate with NO_2 and NH_4 ($P < 0.001$), indicate that silicate was mostly associated with biological activities and/or regeneration from the low oxygen

bottom sediments [3]. Generally, the surface annual mean silicate concentration ($39.83 \pm 28.42 \mu\text{M}$), which was approximately four times higher than that for the bottom mean ($10.22 \pm 6.00 \mu\text{M}$), mainly reflects the direct effect of the discharged silicate enriched UD water. The silicate / dissolved inorganic phosphorus (DIP) ratio was 60:1 [3], confirming the abundance of silicate relative to phosphorus in Mex Bay

In front of the Eastern Harbor (EH)

The concentrations of silicate in front of the EH were relatively low compared with Mex Bay and Abu-Qir Bay, as shown from their surface and bottom annual mean concentrations (Tables 1, 2 and 3). This coastal area is subjected mainly to untreated domestic sewage discharges through Kayet Bey and Silselah outfalls. The low silicate concentrations in this coastal region might be due to the lack of industrial operations in the neighborhood, as well as its comparatively high salinity content caused by mixing with the Mediterranean coastal waters. The importance of the variations in the concentrations of silicate with ‰ in the mixing zones and estuaries has previously attracted the attention of several authors [14, 15, 16]. Liss and Pointon [16] pointed out the possible formation of hydrous metal oxide phases during mixing process, where metals can remove dissolved silicate from natural waters. The maximum surface regional average value was $14.67 \pm 16.00 \mu\text{M}$ at station II, located in the middle of the transect opposite to Kayet Bey outfall (Fig. 1). The bottom water at station I, located close to this outfall (Fig. 1), showed the maximum regional average value ($5.37 \pm 8.11 \mu\text{M}$). These indicate the role of freshwater discharges from this outfall as the main source of silicate to this coastal region. The silicate values for both surface and bottom water layers showed no correlation neither with the environmental parameters nor with the nutrient salts [3]. The regression equation for silicate versus ‰ in the surface water; $\text{silicate } (\mu\text{M}) = 0.615 + 0.247 \text{ ‰}$ indicates that in the freshwater, where ‰ = 0.00, the corresponding silicate concentration gives a value of $0.615 \mu\text{M}$, which must be expected at station I subjected directly to freshwater discharges. The calculated silicate value also confirms that Kayet Bey outfall was the main source of silicate in front of the EH. This is also confirmed by the surface annual silicate mean value ($8.84 \pm 8.21 \mu\text{M}$), which was almost double that of the bottom mean ($3.26 \pm 3.33 \mu\text{M}$).

Abu-Qir Bay

Table 3 shows that the maximum seasonal average silicate values for the surface and bottom waters appeared in October (54.69 ± 22.53 and $35.73 \pm 32.79 \mu\text{M}$, respectively). The relative increase in silicate concentrations in October might be attributed to the decrease in its uptake by low phytoplankton crop in autumn. This phenomenon was stressed earlier by Wallast and De Broeu [15] and Riley and Chester [17], who reported that larger removal of silicate could occur when biological production was high. The surface and bottom waters at station V, located opposite to Abu-Qir Fertilizers and Chemicals Company (Fig. 2) effluents, exhibited the

maximum regional average silicate values (35.28 ± 28.37 and 35.73 ± 19.04 μM , respectively). This confirms the direct effects of the discharged wastes from these plants. The statistically significant correlation of silicate against particulate phosphorus (PP) for both surface and bottom waters ($P < 0.001$) indicates that the effluent of this Fertilizers Company might be the major contributor of silicate to this bay, in addition to the TPS receiving the wastes from another seven effluents via Abu-Qir Drain, which was considered to be the second important source of silicate to this bay [3]. The regression equations vs ‰ for the surface water was; silicate (μM) = $34.697 - 0.376$ ‰ and for the bottom water it was; silicate (μM) = $2.826 + 0.481$ ‰. This indicates that Abu-Qir Fertilizers and Chemicals Company effluents mainly affected the silicate levels in Abu-Qir Bay. Generally, the surface water in Abu-Qir Bay showed an annual silicate mean of 24.03 ± 18.58 μM , which was higher than that for the bottom mean (18.13 ± 11.47 μM). According to Younes [3], silicate followed a reverse dispersion behavior to that of salinity despite the insignificant correlation between them ($P < 1.0$); silicate generally decreased with depth and with distance from the land-based sources of pollution.

Land Based Sources (LBS)

The effluent of RPC showed higher absolute silicate values compared with the other effluents located in Abu-Qir region (Table 4). This might be due to the amount of untreated wastewaters discharged, which was higher compared with the other effluents, averaging $50 \times 10^3 \text{ m}^3\text{d}^{-1}$. The absolute values of this effluent, ranging from 2.71 μM in April to 278.90 μM in July, have led to the regional average value of 115.30 ± 104.95 μM . As a result, TPS was greatly affected by the RPC effluent, reaching an average value of 105.83 ± 144.83 μM .

In Mex region, the MCC effluent exhibited the high regional average silicate value of 89.56 ± 135.29 μM . This might be resulted from the extraordinary high absolute value in July (323.20 μM). On the other hand, UD also exhibited a high absolute silicate value in July (180.20 μM), resulting probably from the intensive freshwater discharges during the summer season, which subsequently led to a comparatively high average value of 63.04 ± 68.98 μM . Both effluents affected the silicate levels in Mex Bay, mainly at the inshore stations.

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