

OBSERVATIONS ON SOME HYDROCHEMICAL ASPECTS OF THE UNITED ARAB EMIRATES WATERS ALONG THE ARABIAN GULF AND THE GULF OF OMAN

By

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بعض الخصائص الهيدروكيميائية لمياه دولة الإمارات العربية المتحدة المطلة

على الخليج العربي وخليج عمان

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تمت دراسة التغيرات الفصلية والمكانية لبعض الصفات الهيدروكيميائية مثل درجة الحرارة - الملوحة - النفاذية - الأس الهيدروجيني - الأكسجين المذاب - الأملاح المغذية (الأمونيا - النيتريت - النترات - الفوسفات - السيليكات) في مياه دولة الإمارات العربية المتحدة المطلة على الخليج العربي وخليج عمان خلال الفترة من أكتوبر ١٩٩٣ وحتى سبتمبر ١٩٩٥ . أوضحت الدراسة وجود تغيرات فصلية ومكانية واضحة في معظم الصفات الهيدروكيميائية وخصوصاً درجات الحرارة - الملوحة وبعض الأملاح المغذية . أوضحت الدراسة أيضاً ارتفاع درجات الملوحة وارتفاع تركيز الأمونيا في مياه الخليج العربي عنها في مياه خليج عمان وبالعكس تميزت مياه خليج عمان بزيادة تركيز الأكسجين المذاب ومعظم الأملاح المغذية مثل النيتريت - النترات - الفوسفات - السيليكات مما يدل على زيادة إنتاجية مياه الدولة المطلة على خليج عمان . أوضحت الدراسة أيضاً أن نسب النيتروجين والفسفور والسيلكون في مياه الدولة بوجه عام اختلفت خصوصاً في منطقة خليج عمان عن النسب العادية، وقد دلت هذه النسب على أن الفسفور هو العامل المحدد في المنطقة .

Key words: Hydrochemical Aspects, United Arab Emirates.

ABSTRACT

Surface and bottom water samples were collected from the United Arab Emirates waters along the Arabian Gulf and the Gulf of Oman during the period from October 1993 to September 1995. Samples were analyzed for temperature (21.1-33.5 oC), salinity (35.86-43.20 ‰), pH (7.94-8.40), transparency (4.5-17.5 m), dissolved oxygen (3.94-8.72 mg/l), ammonia (ND-22.7 µg-at N/l), nitrite (ND-2.16 µg-at N/l), nitrate (ND-18.12 µg-at N/l), phosphate (0.01-4.22 µg-at P/l), and silicate (0.62-15.38 µg-at Si/l). The levels and distributions of the hydrochemical parameters in the investigated area showed that the Arabian Gulf seawater exhibited higher salinity (1.07 times), and ammonia (1.60 times) compared to the Gulf of Oman waters. Meantime, the Gulf of Oman waters were more transparent (1.30 times), and more oxygenated (1.07 times). Moreover, seawater at the Gulf of Oman showed a tendency to concentrate nitrite (1.25 times), nitrate (1.72 times), phosphate (1.40 times), and silicate (1.06 times) which reveal relatively oligotrophic conditions in the Arabian Gulf waters. The Calculated atomic ratios of the elements P:N:Si in seawater of the Arabian Gulf and the Gulf of Oman were, particularly in the Gulf of Oman water, different from Redfield ratio and indicated that inorganic phosphorus was the limiting factor.

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INTRODUCTION

The marine environment of the United Arab Emirates (U. A. E.) is an important aspect since the country enjoys a coastline of about 800 km along the Arabian Gulf and the Gulf of Oman. Recently, the United Arab Emirates has witnessed a rapid economical development and expanded urbanization. Consequently, the marine environment is nowadays facing continuous threats from increasing quantities of chemical and biological contaminants. These contaminants that contaminate marine environments in various ways may cause human health problems [1-3].

The hydrography and chemical characteristics of the Arabian Gulf and the Gulf of Oman have been investigated by several workers [4-7]. However, information concerning hydrochemical properties of the United Arab Emirates waters along the Arabian Gulf and the Gulf of Oman were very limited.

The present study was aimed to investigate levels and distributions of some hydrochemical parameters in the United Arab Emirates along the Arabian Gulf and the Gulf of Oman.

MATERIALS AND METHODS

Surface and bottom seawater samples were collected monthly during 1993-1995 from ten hydrographic stations selected to cover the United Arab Emirates waters along the Arabian Gulf and the Gulf of Oman (Fig. 1). All samples collected for nutrients were immediately treated with 0.5 % chloroform to prevent or at least to minimize changes and were kept in well-stoppered polyethylene bottles. Samples were frozen at extremely low temperature

(-25 °C). The samples were analyzed for the following hydrochemical parameters: temperature, salinity, transparency, pH, dissolved oxygen, and nutrient salts (ammonia, nitrite, nitrate, phosphate, and silicate).

Air and seawater temperatures were measured using an ordinary thermometer graduated to 0.1 °C. Bottom seawater temperatures were measured by using a protected thermometer with a scale ranging from -5 to 31°C, attached to the Nansen bottle. Salinity measurements were carried out using a calibrated labcomp model SCT-1000 salinometer. A standard Secchi disc of 20 cms diameter was used for the measurements of transparency of the water. pH measurements were done using a portable pH-meter (HANNA HI 8314 membrane pH meter). The dissolved oxygen (DO) was determined by classical winkler method, taking into consideration all precautions [8]. Determinations of nutrient salts like ammonia, nitrite, nitrate, phosphate, and silicate were carried out spectrophotometrically [8]. Reproducibility, as expressed by the standard deviation of triplicate analysis, for temperature, salinity, Secchi disc readings, pH, dissolved oxygen, ammonia, nitrite, nitrate, phosphate, and silicate were $\pm 0.1^\circ\text{C}$, $\pm 0.01\%$, $\pm 0.01\text{m}$, ± 0.005 , $\pm 0.04\text{mg/l}$, ± 0.005 $\mu\text{g-at N/l}$, $+0.02$ $\mu\text{g-at N/l}$, ± 0.2 $\mu\text{g-at N/l}$, ± 0.006 $\mu\text{g-at P/l}$, and ± 0.025 $\mu\text{g-at Si/l}$, respectively.

RESULTS AND DISCUSSION

Ranges and mean values of temperature, salinity, pH, transparency, dissolved oxygen, and nutrient salts in the U. A. E. waters along the Arabian Gulf and the Gulf of Oman are given in (Table 1).

Table 1

Ranges and mean values (\pm SD) of different hydrochemical parameters in the United Arab Emirates waters along the Arabian Gulf and the Gulf of Oman.

Area Parameters		The Arabian Gulf coast		The Gulf of Oman coast	
		Range	Mean \pm SD	Range	Mean \pm SD
Temperature ($^{\circ}$ C)	S	21.10 - 33.50	27.76 \pm 0.3	23.10 - 33.00	27.81 \pm 0.1
	B	21.11 - 33.50	27.77 \pm 0.6	23.11 - 32.10	26.00 \pm 0.9
Salinity (S%)	S	36.80 - 43.16	38.85 \pm 1.6	35.86 - 37.74	36.48 \pm 0.7
	B	37.10 - 43.20	39.13 \pm 1.7	35.86 - 37.74	36.46 \pm 0.8
Transparency		4.50 - 13.00	8.70 \pm 0.5	5.00 - 17.50	11.05 \pm 1.2
pH	S	7.96 - 8.29	8.11 \pm 0.1	7.94 - 8.80	8.15 \pm 0.1
	B	7.97 - 8.28	8.12 \pm 0.1	7.91 - 8.30	8.09 \pm 0.1
Dissolved Oxygen (mg/l)	S	3.96 - 8.56	6.02 \pm 0.4	5.18 - 8.72	6.78 \pm 0.1
	B	3.97 - 8.39	5.78 \pm 0.4	2.62 - 8.39	6.00 \pm 0.2
Ammonia (μ g-at N/l)	S	ND - 22.70	2.00 \pm 0.8	ND - 2.66	1.03 \pm 0.1
	B	ND - 12.11	1.38 \pm 0.3	ND - 4.46	1.04 \pm 0.3
Nitrite (μ g-at N/l)	S	ND - 2.16	0.26 \pm 0.2	ND - 1.40	0.26 \pm 0.1
	B	ND - 2.14	0.31 \pm 0.2	ND - 1.73	0.44 \pm 0.1
Nitrate (μ g-at N/l)	S	0.15 - 7.47	2.04 \pm 0.3	0.17 - 15.30	3.02 \pm 0.6
	B	ND - 8.04	1.99 \pm 0.3	ND - 18.12	3.94 \pm 0.6
Phosphate (μ g-at P/l)	S	0.03 - 1.16	0.29 \pm 0.1	0.03 - 4.22	0.39 \pm 0.2
	B	0.01 - 1.45	0.38 \pm 0.2	0.07 - 1.58	0.53 \pm 0.1
Silicate (μ g-at Si/l)	S	0.62 - 12.58	5.13 \pm 1.3	0.68 - 10.56	5.58 \pm 0.3
	B	0.94 - 15.38	5.79 \pm 1.1	1.60 - 12.92	6.22 \pm 0.8

S: surface samples

B: Bottom samples

ND: Not detected

1. Temperature:

Variations of seawater temperatures in both areas followed that of air temperatures in different months. Highest average values for the Arabian Gulf and the Gulf of Oman seawater (32.90 & 30.45 °C) were achieved in August when air temperatures reached their maximum average value (36.0 °C). Whereas, lowest averages (22.3 & 23.4 °C) were found in February when air temperatures were low (21.4 °C). Air temperatures were lower than surface water temperatures during most of the winter season. When the water surface is warmer than the overlying air, a loss of heat from the sea to the atmosphere and high evaporation can occur leading to an increase in the density of the surface water which create favorable conditions for winter convection and sinking of surface water. During the summer season, the reverse happened and a gain of heat from the atmosphere to the sea increased the stability and stratification in the water column. Regional variations, on the other hand, revealed insignificant differences between seawater temperature of the Arabian Gulf (27.77 °C) and the Gulf of Oman (26.90 °C).

2. Salinity:

Due to the shallowness of the Arabian Gulf and the slow rate of water exchange with the Gulf of Oman which

is considered as an extension of the Indian Ocean, the seawater at the Arabian Gulf (38.99%) showed higher salinity values compared to the Gulf of Oman (36.47%). Regional distributions indicated also an increase in salinity levels towards the innerparts of the Gulf, i.e. station I (41.62 & 41.94 %) compared to outerparts, i.e. station V (37.88 & 38.07%). Due to the sinking of the dense more saline seawater, salinity variations with depth, in the two regions, were maximum during summer months. During winter months increased mixing reduced the vertical salinity gradients substantially. Seasonal variations, on the other hand, revealed insignificant differences in the Arabian Gulf between the salinity of the winter season (39.27%) and the summer season (38.98 %) due to the scarcity of rainfall in the winter season during the period of investigation. The penetration of the less saline water from the Gulf of Oman into the Arabian Gulf during summer months was also behind the decrease in the summer season despite of higher rate of evaporation [10]. At the Gulf of Oman, no significant regional variations were observed. Moreover, the pattern of distribution was similar to that of open seawater as the more saline waters (36.53%) were measured in the summer season and the less saline (35.98 %) in the winter season.

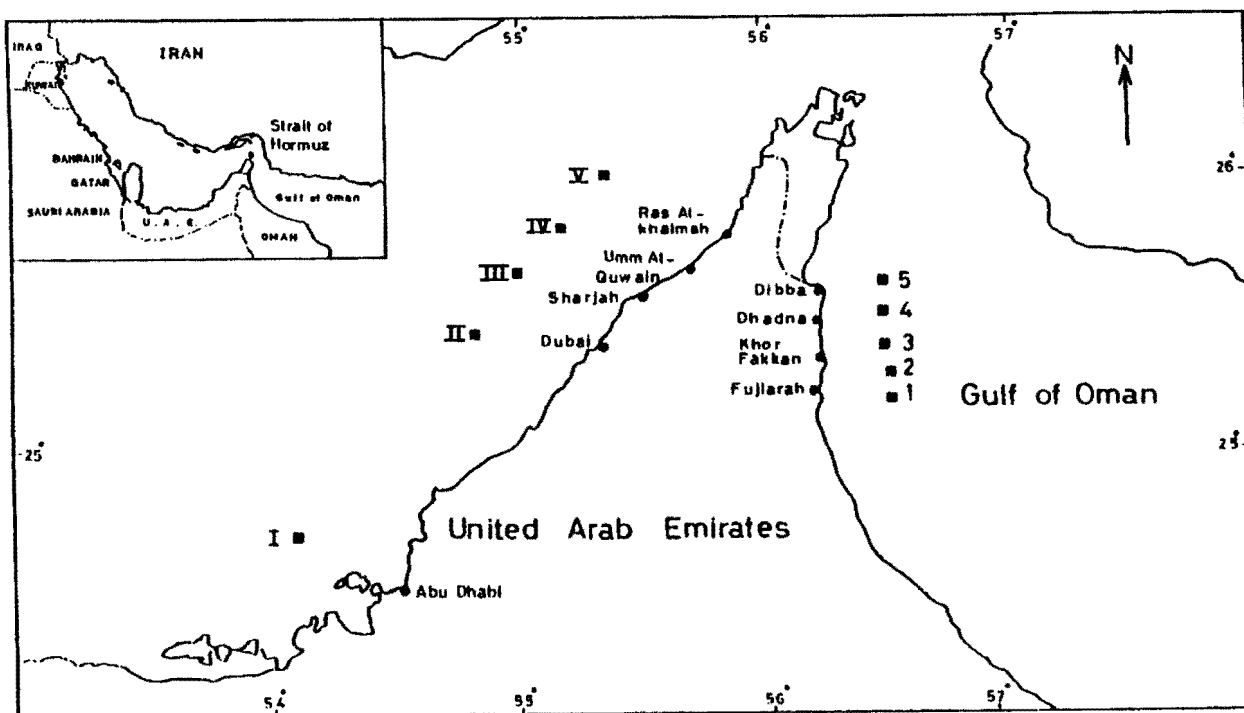


Fig. 1 Locations of Sampling Stations.

3. Transparency:

Secchi disc readings, which are still widely used to measure the transparency of waters in the marine environment, were much higher (11.05 m) at the Gulf of Oman (Table 1 & Fig. 2) than the Arabian Gulf (8.70 m) revealing more transparent water at the Gulf of Oman despite of its higher contents of chlorophyll and plankton density [9]. Worth noting that tidal currents of significant magnitude often increase the turbidity in shallow semiclosed basins like the Arabian Gulf and limit the light penetration to a considerable extent. The low secchi disc reading at the Arabian Gulf were mainly due to the higher suspended sediment load which were associated with the relatively strong tidal currents at the Arabian Gulf [10] in addition to inorganic suspended particles resulting from tankers wastes as well as the movements of tankers in such shallow area which churned up bottom sediments into suspension. Among all stations, higher transparency levels were observed in the Gulf of Oman water at station 2 (11.92 m) and less transparency at station 5 (9.06 m). The lower secchi disc readings at station 5 were associated with the turbidity caused by high plankton density in this area [9]. At the Arabian Gulf, secchi disc readings indicated a tendency to decrease towards the innerparts, i.e., station V

(8.53 m) > station I (7.85 m). Earlier work [10] indicated relatively high suspended sediment load in the innerparts of the Arabian Gulf. Seasonal variations in the Arabian Gulf water indicated insignificant differences between secchi disc readings during the summer season (8.65 & 8.53). At the Gulf of Oman, higher secchi disc readings were observed during summer months (10.72 m) compared to winter months (8.95 m). The low transparency during the winter season could be due to turbulence in the water column. Yet another reason for the low transparency in a dynamic environment could be the fact that more light would be reflected from ruffled surface than a calm one [11].

4. Hydrogen ion concentration (pH):

The pH displayed very limited variations in the area. Vertical distributions of pH were more pronounced at the Gulf of Oman (8.15 & 8.09) and indicated a slight decrease with depth due to increased photosynthetic activity near the surface and the decomposition of organic materials and plants remains near the bottom. Seasonal variations, on the other hand, showed higher values in the two regions (8.15 & 8.13) during the winter season than the summer season (8.02 & 8.02). The low pH measured in the summer season

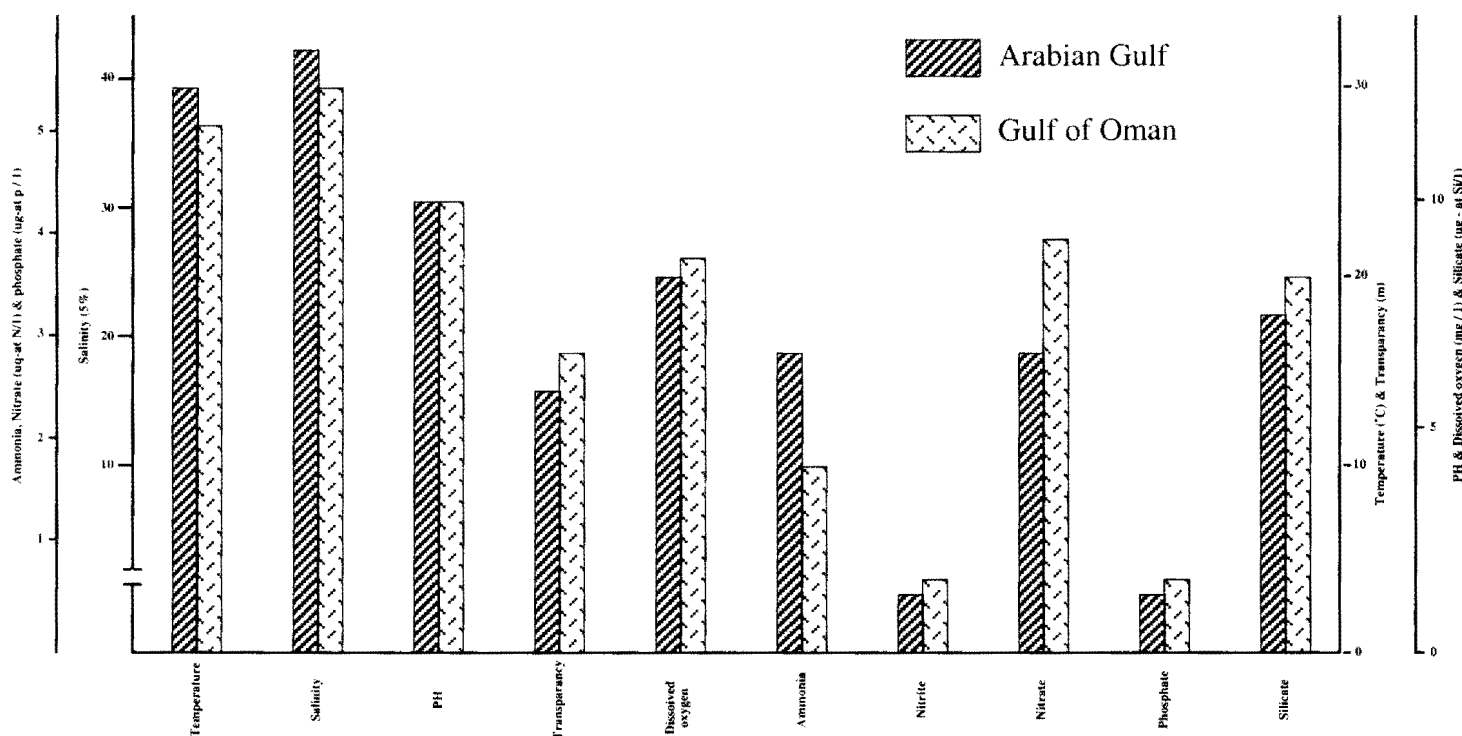


Fig. 2 Comparison Between The Average Values of The Various Hydrochemical Parameters In The Arabian Gulf of Oman Waters

were matched by a relative decrease in the concentrations of dissolved oxygen. A comparison between the pH values in the two regions (Fig.2) revealed no significant regional variations. Moreover, the variations between different stations in the two regions were also not significant.

5. Dissolved oxygen:

Dissolved oxygen distributions showed higher concentrations in surface water at the Arabian Gulf (6.02 mg/l, 95.7 sat. %) and the Gulf of Oman (6.78 mg/l, 106.0 sat. %) compared to bottom (5.70 mg/l, 90.5 sat. % & 6.08 mg/l, 92.0 sat. %) seawater (Table 1). The higher values found at the surface were mainly due to increased rate of photosynthetic activity and exchange at air-sea interface. Meantime, the relatively low oxygen values recorded at the bottom might be a result of the decomposition of organic materials near the bottom. The seawater in the two regions was more oxygenated (6.47 mg/l, 96.2 sat. % & 6.80 mg/l, 99.4 sat. %) during the winter season due to a decrease in water temperatures and water agitation. Whereas, less oxygenated seawater (5.18 mg/l, 85.0 sat. % & 5.38 mg/l, 83.2 sat. %) were observed in the summer season. The decrease in the summer season was due the rise of water temperatures leading to a decrease in the exchange at air-sea interface; decrease in the rate of aeration due to stagnation of seawater caused by calm weather; and increase in the rate of the decomposition of organic materials due to higher temperatures. Another important feature in the distribution of dissolved oxygen was the higher levels (6.39 mg/l, 98.5 sat. %) at the Gulf of Oman as compared to the Arabian Gulf (5.86 mg/l, 93.8 sat. %) indicating more oxygenated seawater at the Gulf of Oman (Table 1 & Fig. 2) due to the higher rate of photosynthetic activity [9] and increased aeration on account of the active winds. Another important reason was the lower water temperature and salinity values at the Gulf of Oman. Among all stations; station I (6.52 mg/l, 104.3 sat. %) at the Arabian Gulf and station 5 (6.55 mg/l, 94.5 sat. %) at the Gulf of Oman were characterized by their higher oxygen contents due to an increase, particularly at station 5, in the rate of photosynthetic activity [9].

6. Nutrient salts:

Seasonal variations of nutrient salts indicated high

average values for ammonia (2.41 $\mu\text{g-at N/l}$), nitrite (0.37 $\mu\text{g-at N/l}$), nitrate (2.26 $\mu\text{g-at N/l}$), phosphate(0.44 $\mu\text{g-at P/l}$) during winter months when mean surface and bottom water temperatures were at minimum (23.77 °C). On the other hand, low values of ammonia (1.18 $\mu\text{g-at N/l}$), nitrite (0.23 $\mu\text{g-at N/l}$), nitrate (1.90 $\mu\text{g-at N/l}$), phosphate (0.30 $\mu\text{g-at P/l}$) were obtained in summer months when surface and bottom water temperatures were at maximum (30.39 °C). Similarly, seasonal variations of nutrient salts at the Gulf of Oman indicated high concentrations of ammonia (1.16 $\mu\text{g-at N/l}$), nitrite (0.48 $\mu\text{g-at N/l}$), and phosphate (0.53 $\mu\text{g-at P/l}$) during winter months when mean surface and bottom seawater temperatures were at minimum (24.02 °C). The higher nutrient salts measured in the winter season were due to the mixing processes that bring nutrient-rich deeper water to the surface [12-15]. The low values of ammonia (0.94 $\mu\text{g-at N/l}$), nitrite (0.36 $\mu\text{g-at N/l}$), and phosphate (0.41 $\mu\text{g-at P/l}$) were obtained when seawater temperatures reached their maximum (29.17 °C). The lower values in the summer season were principally due to the increase in the uptake of nutrients by phytoplankton which were abundant in the summer season [16-18]. Distributions of silicate in the area showed higher values in seawater of the Arabian Gulf and the Gulf of Oman (5.85 & 5.95 $\mu\text{g-at Si/l}$) during summer months when seawater temperatures were at maximum (30.44 & 30.47 °C). The increase in silicate concentrations during the summer season was probably due to the increase in the dissolution rate of shell material. On the other hand, lower values (4.80 & 5.40 $\mu\text{g-at Si/l}$) were measured during winter months when seawater temperatures were at minimum (23.77 & 24.02 °C). The low values and the minimum average value measured in the winter season were due to utilization of silicate by organisms mainly diatoms which were abundant in the summer season. Vertical distributions of nutrient salts in the area showed a tendency to increase with depth (Table1) due to their uptake in the euphotic zone, regeneration from organic materials in bottom layers, biochemical degradation, zooplankton and animal excretion and release from sediments [19-22]. Another important feature in the distribution of nutrient salts in the investigated area was their higher levels at the Gulf of Oman, i.e. nitrate (1.72 times), phosphate (1.40 times), nitrite (1.25 times) and

Table 2

**The average atomic ratios of the elements phosphorus: nitrogen: silicon:
in the United Arab Emirates waters along the Arabian Gulf and the Gulf of Oman.**

Area Parameters	The Arabian Gulf Coast of the United Arab Emirates	The Gulf of Oman Coast of the United Arab Emirates
Inorganic phosphorus ($\mu\text{g-at P/l}$)	0.34	0.46
Inorganic nitrogen ($\mu\text{g-at N/l}$)	3.98	4.86
Inorganic silicon ($\mu\text{g-at Si/l}$)	5.55	5.90
Atomic ratios P:N:Si	1: 11.7: 16.3	1: 10.6: 12.8

silicate (1.06 times) compared to the Arabian Gulf seawater indicating more oligotrophic conditions in the Arabian Gulf (Fig. 2).

7. Phosphorus: Nitrogen: Silicon Atomic Ratios:

It is well known [23-24] that concentrations of major nutrients, such as nitrate, phosphate, and silicate in seawater change in relation to fixed concentration ratios in organisms (1:15:15). Moreover, the availability of nutrients (25) can limit the plankton growth and the limiting nutrients are usually being considered to be nitrate and phosphate, although silicate can limit diatom growth.

The calculated atomic ratios of the elements phosphorus: nitrogen: silicon in seawater of the United Arab Emirates along the Arabian Gulf (1:11.7:16.3) and the Gulf of Oman (1:10.6:12.8) were, particularly in the Gulf of Oman water, different from Redfield ratio and indicated that inorganic phosphorus was the limiting factor.

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