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Chemical Observations in the Arabian Gulf and the Gulf of Oman

Mohamed I. El Samra

Marine Sciences Department,
University of Qatar, Qatar

ABSTRACT. Salinity and nutrient species were measured in the Arabian Gulf and the Gulf of Oman during the period 1984-1986. Statistical analysis of the results showed clearly three distinct types of seawater in the area. First is the proper water of the Arabian Gulf with salinity $\geq 40‰$, silicate from 2.6 to 9.3 μmole l^{-1}, phosphate 0.14 $\pm$ 0.02 μmole l^{-1} and nitrate 0.21 $\pm$ 0.02 μmole l^{-1}. Second is the seawater of the Gulf of Oman with salinity $\leq 37‰$, silicate 3.1 $\pm$ 0.3 μmole l^{-1}, phosphate 0.47 $\pm$ 0.05 μmole l^{-1} and nitrate 0.41 $\pm$ 0.05 μmole l^{-1}. Third is a mixed water, which has intermediate values of the measured elements. The calculated ratios for P:N:Si indicate the nitrogen deficiency in the Arabian Gulf.

There are very few published observations on hydrographical and hydrochemical conditions of the Gulf region. The work done on R.V. Meteor in March, 1965 (Grasshoff 1976), and the work conducted on R.V. Atlantis II cruise 93 in February and March, 1977 (Brewer and Dyrssen 1985) are among the few extensive works. They deal mainly with the Iranian side of the Arabian Gulf and the Gulf of Oman. Other sporadic studies are of local importance and mainly on the fisheries with some supplementary chemical observations (Kuronuma 1974, Jacob *et al.* 1982, and Emara *et al.* 1985).

The present paper presents the results of chemical oceanographic studies focused particularly on the Arabian Shelf, which complement the earlier investigations.

Sampling and Methods

The data presented here are the results of 3 cruises made by R.V. Mukhtabar Al-Bihar in the Gulf Region. The first cruise was made in October-November, 1984 to cover the northern part of the Arabian Gulf, and the second in September-October, 1985 to cover the southern part of the Arabian Gulf. The third was made in September-October, 1986 to cover the latter area and extended to cover the Strait of Hormuz and an area of the Gulf of Oman to Muscat (Fig. 1).

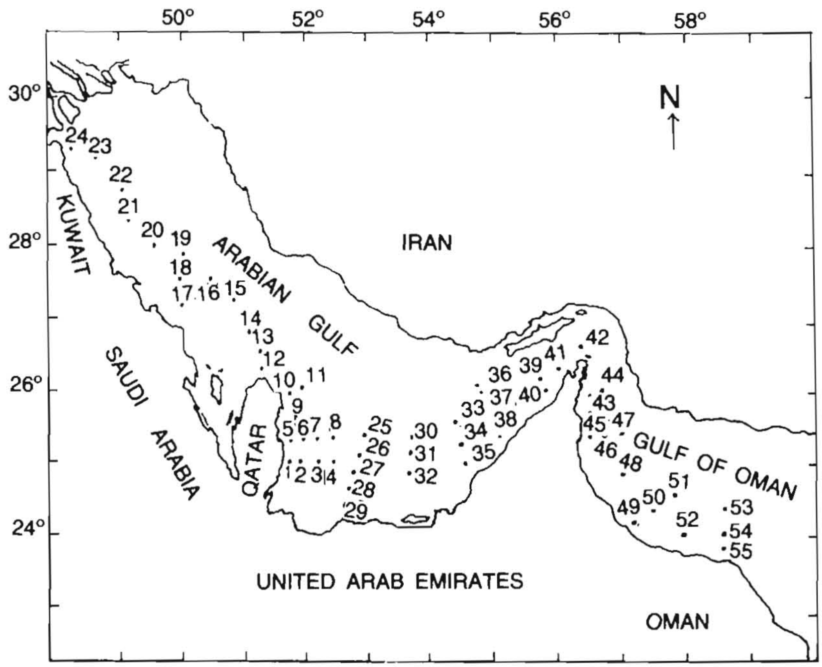

Fig. 1. Stations sampled in the Arabian Gulf and the Gulf of Oman.

Seawater samples were collected from the different stations at different depths by Nansen bottles. Phosphate, nitrate and dissolved silicon (silicate) were determined according to the methods described by Strickland and Parsons (1968). Salinity was obtained with a temperature compensated salinometer model Autolab 601 MK III.

Results and Discussion

According to the compiled data by previous works and to the present repetition of water analysis made off Qatar and UAE, minimum annual changes in chemical and physical parameters were found to occur in the area of investigation. Therefore, the present observations, made through 3 cruises, will be pooled, extrapolated and presented as if they were synoptic.

The horizontal distribution of salinity (Fig. 2), shows a typical increase of the surface values from about 37‰ for the water of the Gulf of Oman to values higher than 40‰ for that of the Arabian Gulf. These values are in agreement with those obtained by other workers (Grasshoff 1976, and Brewer and Dyrssen 1985). The coastal water of Qatar and UAE showed the highest salinities (≃ 43‰).

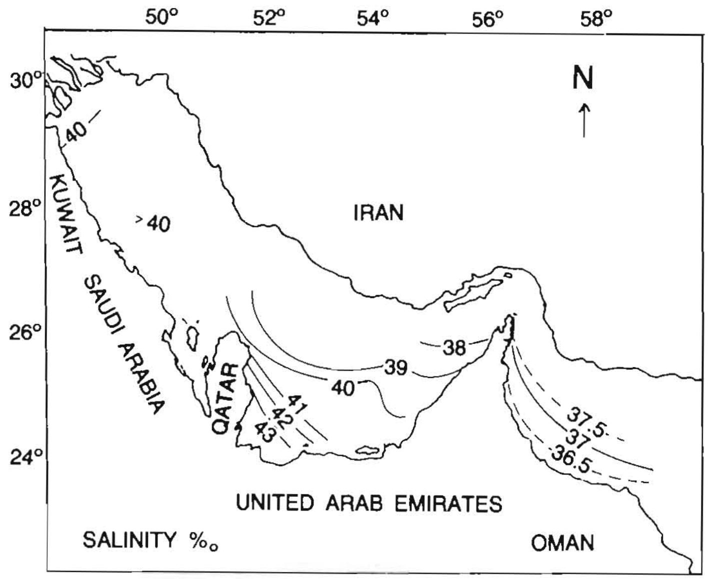

Fig. 2. Distribution of surface salinity ‰.

The isohaline 38‰ occurs within the Arabian Gulf around the northeastern coast of UAE indicating surface inflow of less saline water from the Gulf of Oman through the Strait of Hormuz. This type of surface gradient of isohalines is an extension of those given by Brewer and Dyrssen (1985) for the Iranian coast. Hunter (1984) stated that a surface inflow from the Gulf of Oman could reach the region north of UAE. The isohaline of salinity 39‰ was found to reach very close to the northern coast of Qatar indicating that the surface inflow could be advected to that area at least in autumn. The results (Fig. 3) show that marked stratification occurs in the Strait of Hormuz (stations 41, 42) and some other stations, reflecting the presence of water with a salinity that is reduced as a result of mixing, overlying water of higher salinity more typical of the Arabian Gulf. In these areas where mixed water is present there is a halocline in the depth range of about 10-50 metres, contrasting with the regions of greater homogeneity, exemplified by stations 8 and 46.

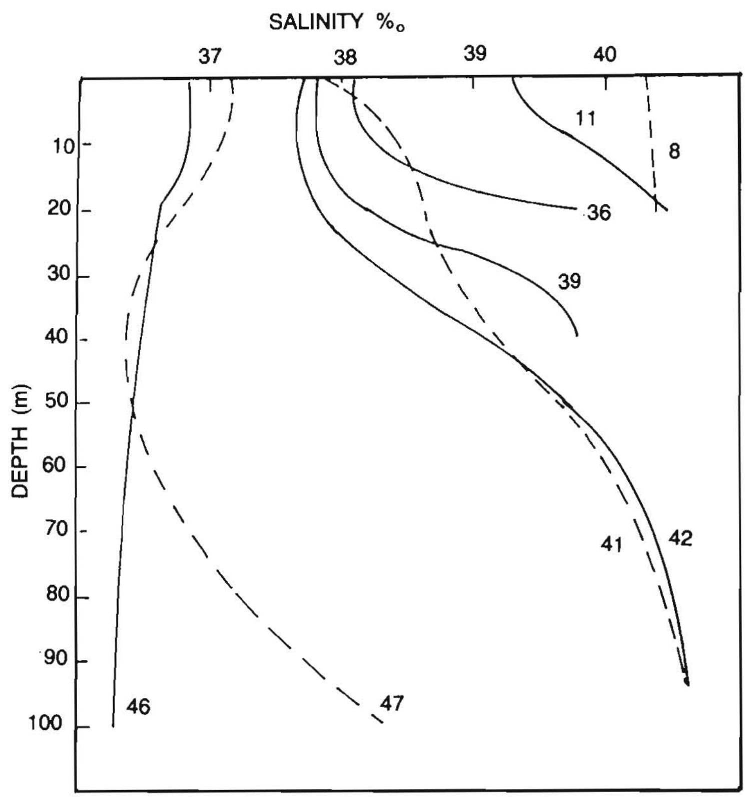

Fig. 3. Salinity-depth profiles within the water column at some stations.

The inflow of nutrient (phosphate and nitrate)-rich water from the Gulf of Oman into the Arabian Gulf (a physical process noted by Grasshoff 1976 and Brewer and Dyrssen 1985) could reach the northeastern coast of UAE and to very near to the north coast of Qatar as indicated by isolines of nutrients in Figs. 4, 5 and 6. Mean values of nutrients, as shown in the histograms in the figures and in Table 1, show a more or less decreasing trend of phosphate from the Gulf of Oman to the Arabian Gulf. However, the highest values of phosphate and nitrate, masured in the Arabian Gulf, reflect the effects of the land discharge by fertilizer industry at the south of Qatar. In general, the Gulf of Oman showed higher phosphate and nitrate concentrations as compared to the Arabian Gulf due to upwelling in the former (Grasshoff 1976).

Table 1. Concentrations, µmole l^{-1}, of phosphate-P, nitrate-N and silicate-Si in surface water of the different areas in the Gulf Region.

Area	Phosphate-P	Nitrate-N	Silicate-Si
Gulf of Oman	0.47 ± 0.05	0.41 ± 0.05	3.1 ± 0.3
Strait of Hormuz	0.36 ± 0.09	0.20 ± 0.03	0.7 ± 0.2
U.A.E.	0.23 ± 0.05	0.23 ± 0.03	2.9 ± 0.5
Qatar	0.14 ± 0.02	0.21 ± 0.02	2.6 ± 0.3
Kuwait & Saudi Arabia	0.12 ± 0.02	0.26 ± 0.02	9.3 ± 1.5

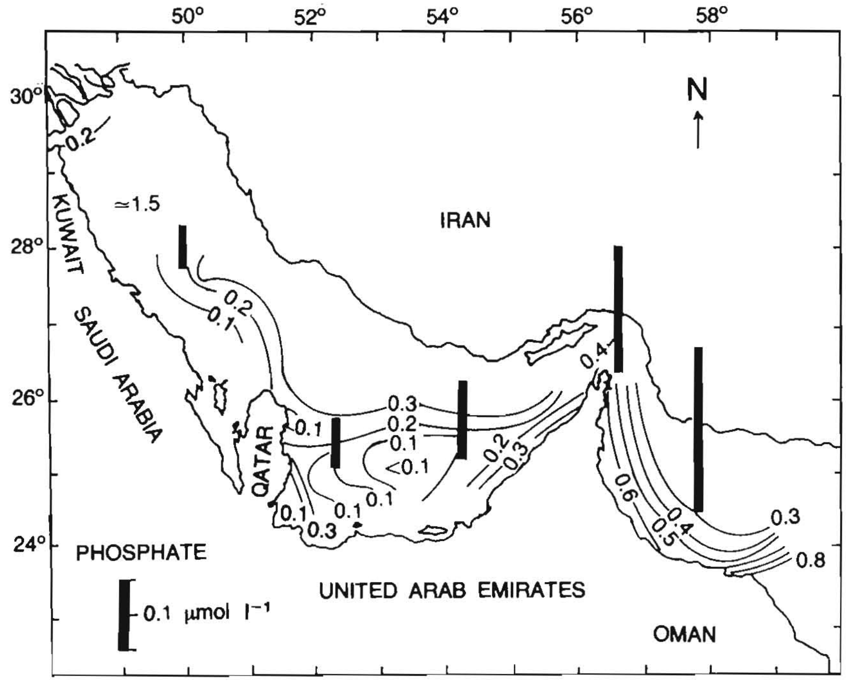

Fig. 4. Surface distribution of phosphate, µmole l^{-1}, histograms represent mean values.

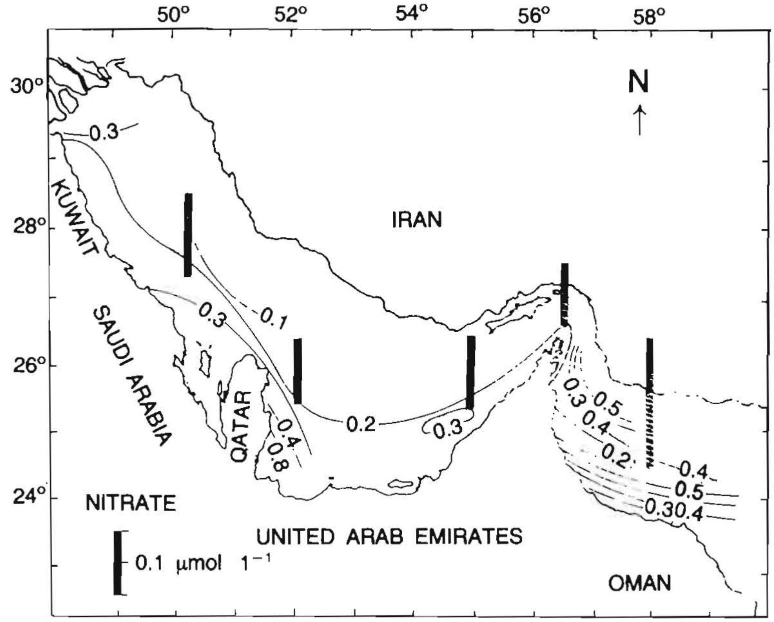

Fig. 5. Surface distribution of nitrate, μmole l^{-1}, histograms represent mean values.

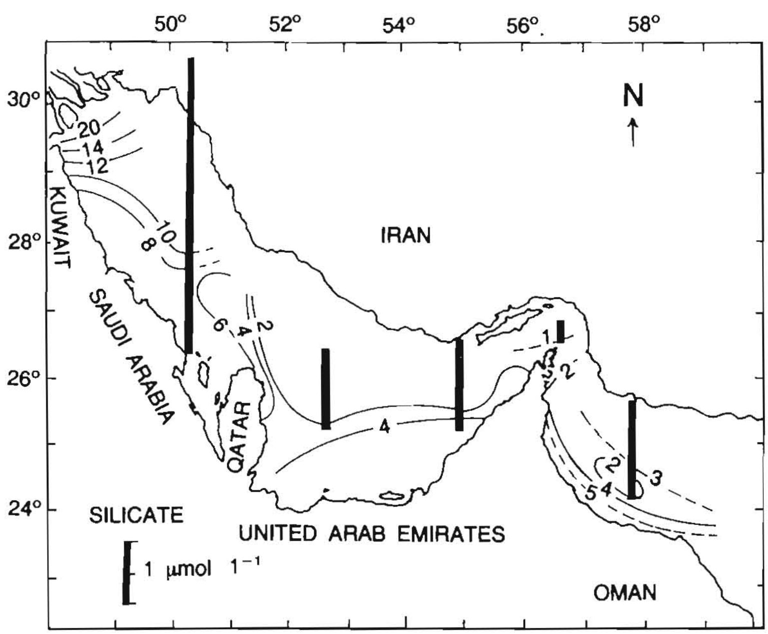

Fig. 6. Surface distribution of silicate, μmole l^{-1}, histograms represent mean values.

The low concentrations of nutrients measured at the offshore stations are in good agreement with those found by Brewer and Dyrssen (1985), while the relatively high concentrations at the nearshore water in the Arabian Gulf are in good agreement with those found by Emara *et al.* (1985), Kuronuma (1974), and Jacob *et al.* (1982) off Qatar and Kuwait. The high value of silicate at the north of the Arabian Gulf reflects the effect of fresh water discharged from Shatt Al-Arab area.

A phosphate-salinity plot (Fig. 7) shows linear correlation with $r = -0.94$ and $r = -0.69$ for the Gulf of Oman and the Arabian Gulf, respectively. The plot shows a marked break at the area of mixed water where no correlation could be calculated. Brewer and Dyrssen (1985) found the same break at the Strait of Hormuz.

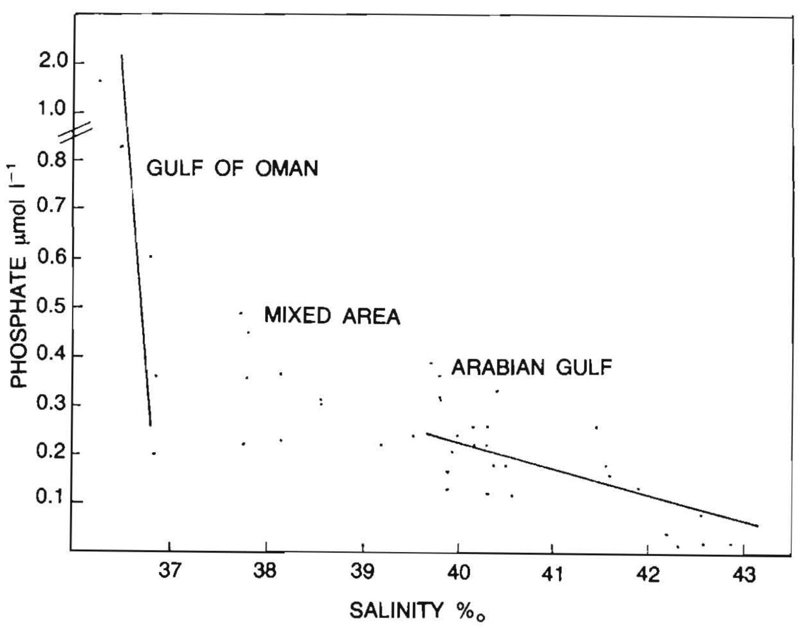

Fig. 7. Phosphate-salinity plot for the different types of water.

A silicate-salinity plot (Fig. 8) indicates linear correlation as well, but with positive sign ($r = 0.84$) and with no break. Accordingly, silicate is not a limiting nutrient in the Arabian Gulf. This is in contrast to the suggestion of Grasshoff (1976) that silicate is the limiting nutrient in the Gulf, as he found low values (0−1

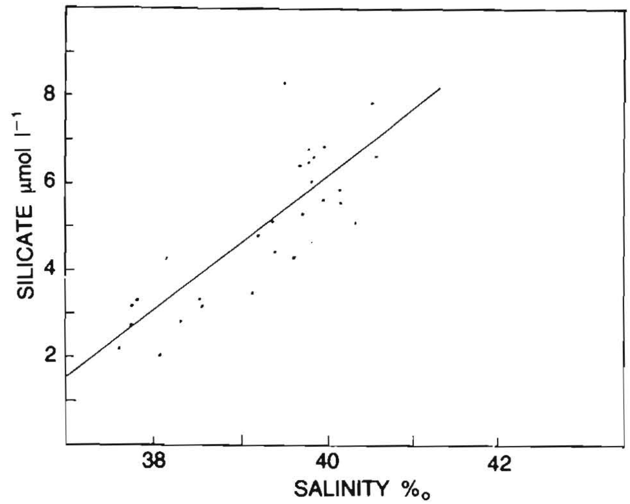

Fig. 8. Silicate-salinity plot for the different types of water.

µmole l^{-1}) at the Strait of Hormuz. Present data show also low values of silicate at the Strait of Hormuz (0.7 ± 0.2 µmole l^{-1}). Grasshoff (1976) attributed low values to the fact that silicate debris mineralises more slowly than organic tissues. Silicate concentrations in the Arabian Gulf, on the other hand, are high. This indicates that biological activity is not utilizing the increased amount of silicates made available by physical mixing within the Gulf water. In addition, the calculated ratios for P:N:Si (Table 2) indicate nitrogen deficiency in the area. Hence, the productivity within the Arabian Gulf is limited by the nitrogenous nutrient and not silicate.

Table 2. The calculated ratio P:N:Si in surface (S) and bottom (B) waters of the different areas in the Gulf Region.

Area		P	:	N	:	Si
Gulf of Oman	S	1		0.9		6.6
	B	1		6.7		9.9
Strait of Hormuz	S	1		0.6		1.9
	B	1		7.5		13.6
U.A.E.	S	1		1.0		12.6
	B	1		2.0		15.0
Qatar	S	1		1.5		18.6
	B	1		3.4		15.8
Kuwait & Saudi Arabia	S	1		2.2		77.7
	B	1		6.7		43.3

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ملاحظات كيميائية بالمنطقة البحرية للخليج العربي وخليج عُمان

محمد إبراهيم السمره

قسم علوم البحار ـ جامعة قطر ـ قطر

يقدم البحث نتائج عن الملوحة والأملاح المغذية (الفوسفات، النيترات، السيليكات) تم جمعها من خلال ٣ رحلات قامت بها سفينة البحوث (مختبر البحار) بالمنطقة في الخليج العربي وخليج عُمان من الكويت إلى مسقط. وقد جمعت عينات مياه من ٥٥ موقع على أعماق مختلفة. وتم تحليل العينات تبعاً للطرق الكيميائية المعروفة. وقد أوضحت النتائج أن الملوحة تتدرج بالزيادة من حوالي ٣٧ بالألف في مياه خليج عُمان إلى أكثر من ٤٠ بالألف في الخليج العربي. أما الفوسفات فإن معدلات تركيزها تتناقص على نفس الإتجاه فتركيزها بخليج عُمان هو ٠,٤٧ ± ٠,٠٥ ميكروغرام فوسفور/ لتر. ويقل في الخليج العربي إلى ٠,١٤ ± ٠,٠٢ ميكروغرام فوسفور/ لتر. والنيترات في خليج عُمان يكون تركيزها ٠,٤١ ± ٠,٠٥ ميكروغرام نيتروجين/ لتر وفي الخليج العربي يقل التركيز إلى ٠,٢١ ± ٠,٠٢ ميكروغرام نيتروجين/ لتر. ولكن وجد أن السيليكات تزداد في الخليج العربي زيادة كبيرة (٩,٣ ميكروغرام سيليكون/ لتر أمام الكويت) عنها في خليج عُمان حيث لا تتعدى في الأخير ٣,١ ± ٣و٠ ميكروغرام سيليكون/ لتر. وتوضح النتائج دخول تيار سطحي من خليج عُمان (ذي ملوحة منخفضة وأملاح مغذية مرتفعة نسبياً) إلى الخليج العربي من خلال مضيق هرمز. ويصل دخول هذا التيار إلى الساحل الشمالي الشرقي للإمارات العربية المتحدة (إلى إمارة الشارقة)، كما يصل إلى مناطق قريبة جداً من الساحل الشمالي الشرقي لدولة قطر. وتوضح النتائج أيضاً وجود ثلاثة أنواع من المياه بالمنطقة، وهذه الأنواع الثلاثة هي المياه الخاصة بخليج عُمان والمياه الخاصة بالخليج العربي بالإضافة إلى منطقة مياه مختلطة تمتد في مساحة بينهما. ومن دراسة تغيير الملوحة مع الأعماق اتضح أن عمود الماء في منطقة المياه المختلطة يكون حاوياً لطبقتين

من المياه، أحداهما سطحية وأصلها من خليج عُمان والأخرى قاعية وأصلها من الخليج العربي. أما المناطق التي لم تتأثر بعملية خلط الخليجين فإن عمود المياه فيها يحوي طبقة واحدة متجانسة ومن أصل واحد فقط. وقد تم عمل علاقات رياضية بين الفوسفات والملوحة في الثلاثة أنواع من المياه ووجد أن العلاقة عكسية في مياه الخليج العربي وخليج عُمان، ولا توجد علاقة في مياه المنطقة المختلطة. أما العلاقات الرياضية بين السيليكات والملوحة فقد بينت أنها علاقة طردية مما يوضح أن الإنتاجية بمنطقة البحث لا تتأثر بالسيليكات. وبدراسة النسبة فوسفور: نيتروجين: سيليكون اتضح أن هناك نقصاً واضحاً جداً للأملاح المغذية النيتروجينية مما يؤكد أن تلك الأملاح هي العناصر المحددة للإنتاجية بالخليج العربي على الأقل حيث إن نسبة النيتروجين إلى الفوسفور تزداد بعض الشيء في المياه القاعية بخليج عُمان. وبعملية تصاعد المياه السائدة بهذا الخليج يجعلها تتزايد في المياه السطحية بالمقارنة بالخليج العربي.