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Chemical Evaluation for Western Coast of Mediterranean Sea in Egypt

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Abstract: pH, dissolved oxygen, oxidizable organic matter, as well as nutrient salts (NH4, NO2, NO3, PO4, and SiO4) were studied in the water of western coast of the Mediterranean Sea in Egypt (west of Alexandria) at different depths ranging from 0-200 m depth for inshore and offshore stations during winter (31 January to 5 February) and summer (3-10 September), 2006. During the last three decades, many touristic cities were constructed along the study coastal area. These coastal areas are exhibiting sings of stress, population pressures, and coastal development may lead to: declining fisheries, proliferation of harmful algal blooms nourished by sewage and agricultural run off close to beaches harming fish and causing health problems. Thus, this paper aimed to assess the eutrophication level in the study area.

Key words: Mediterranean Sea; Eutrophication; Nutrients; Vertical Profile; And Shallow Water.

INTRODUCTION

In the semi-enclosed Mediterranean Sea, nutrients are important tracers of biological cycles, new production, natural and anthropogenic inputs and transfer processes.[1,2] Nutrient budget in the coastal Mediterranean Sea west of Alexandria depends on the water flows and nutrient concentration across the straits of Gibraltar and Sicily, together with atmospheric and terrestrial influxes. The main sources of nutrient salts in the study area from terrestrial environment are the river discharge, coastal water, water outfalls, urban activities, and atmospheric deposition.

The effects of excess nutrients in fresh water have been well understood and documented since the mid 20th century. In contrast, an awareness of the potential importance of eutrophication in the coastal and marine environment has been developing only since the early 1980s.[3]

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Accordingly, the main objective of the present study was to provide systematic data on nutrient salts, dissolved oxygen, and organic matter along the western part of the Mediterranean coast of Egypt to consider the causes and concerns relating to eutrophication in this coastal area.

Study Area

The present study area is the western part of the Mediterranean coast of Egypt extends from Alexandria to Sallum (31˚ 1.2' 29˚ 30' to 32˚ 1.2' 25˚ 25'). Nine short sampling stations were chosen to cover the area of study, among which the stations were located to cover the inshore and offshore areas of the coast. For the station locations, see Fig.1.

MATERIAL AND METHODS

During winter and summer of 2006, two field trips were performed by research vessel belonging to the National Institute of Oceanography and Fisheries. Sampling was performed by Assistant Lecturer Mohamed Abd El-Naby. This study was a part of the research plan of the Institute, development of the pelagic and the demersal fish and invertebrates along the Egyptian coast between Alexandria and Sallum among the predominant environmental conditions.

Temperature and pH were determined in situ at time of sampling using a portable microprocessor based temperature and pH meter model M90. Dissolved oxygen (DO) was analyzed according to the modified Winkler method (Grasshoff 1976).[4] Oxidizable organic matter (OOM) according to Calberg method.[5] Nutrients (NH_4, NO_2, NO_3, PO_4, and SiO_4) were analyzed spectrophotometrically according to oceanographic method described by Grasshof (1976)[4] using Shimadzu double beam spectrophotometer.

RESULTS AND DISCUSSION

The vertical profiles and spatial distribution of pH, dissolved oxygen, oxidizable organic matter, and the N-species (NH_4, NO_2, and NO_3), as well as phosphorus (PO_4) and silicates (SiO_4) are given in Figures 2-a, 2-b, 3-a, 3-b, and 4. Their average values in the whole water column at each of the different stations and sectors are given in Table 1 (a and b).

For the study area, water temperature ranged from 13.0 ºC to 18.0 ºC in winter, while summer season recorded 18.0 ºC to 24.5 ºC . Salinity attained the predominant values of the Mediterranean Sea with average value of 38.5 % in winter and 39.09% in summer.

The recorded pH values at the area of study were in the ranges 7.9-8.7 and 7.80-9.75 during winter and summer, respectively. The relative increase in pH values in summer might be attributed to the rise in temperature which is considered one of the important factors that increases the pH in summer. When the sea water temperature rises, CO_2

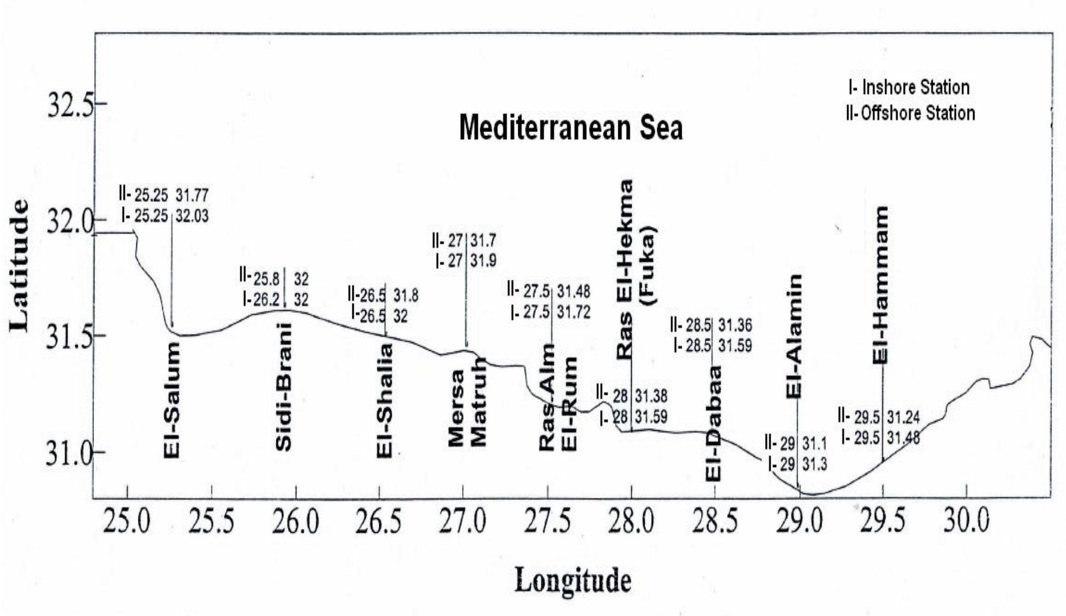

Fig. 1: Coastal area of Mediterranean Sea, West of Alexandria-location of sampling stations

escapes to the air and the decrease in CO_2 in the sea water causes the rise of pH value of sea water. Moreover, the flourishing of phytoplankton during summer consumes CO_2. The pH values exhibited slightly higher values at 100 and 200 m depths in most sections during summer. However, the decrease in pH values during winter season is mainly related to the high bicarbonate content, where the CO_2 uptake by phytoplankton decreases in winter season.[6]

Dissolved Oxygen (DO):

It is a matter o f fact that in the marine environment, DO is greatly affected by air and water temperature, wind mixing, and photosynthetic activity. The concentrations of DO in the water collected from the area of study vary in the ranges 3.49-7.09 ml/L and4.68-6.63 ml/L during winter and summer, respectively. The obtained data showed that the content of dissolved oxygen increases from the low content in the inshore stations to the high content in the offshore stations (Figs. 2-a and 3-a). It can be observed also from the obtained data that the concentration of DO was mostly lower in the water collected from shallow depths compared to those in water collected from deep water depths in the same section. The maximum oxygen content occurs in station II at Sallum with magnitude of 6.79 ml/L during winter. It is a worth indicating that storming winds were prevailing during the period of investigation in summer, though this may play an important role in mixing and aerating water mass of the studied area. Therefore, the whole water columns were well oxygenated during summer.

Oxidizable organic matter (OOM):

Dissolved organic matter has various functions and plays important roles in chemical, biological, and even physical oceanography. Primary production is the ultimate source of organic matter in the sea.[7] OOM was measured in the study area during winter only. The results indicate that

OOM ranged between 0.0 and 3.96 mg O_2/L. Many stations throughout most of the study area recorded 0.0 mg O_2/L OOM, while a maximum of 3.96 mg O_2/L was found in Ras El-Hekma at 100 m depth (Fig. 2-a). Irregular vertical variations of OOM were observed for almost all stations. This may be attributed somehow to vertical mixing of waters in winter under the effect of the prevailing wind and regime of water current.

Significant low values of OOM were noticed at inshore and offshore stations of El-Sallum section (Fig. 4). This expected low level of OOM might be attributed to the location of this section far from the land-runoff related to the human and agricultural activities. Generally, insignificant difference of OOM between the inshore and offshore stations among the studied sections was observed (Fig. 4).

Nutrient Concentrations:

Vertical distribution: The water column profiles of inshore and offshore stations, generally, showed high concentrations of inorganic nitrogen forms, phosphate and silicate at the surface water followed by sharp decreasing in concentrations down to 25 m depth. Obvious high concentrations of all nutrients except NH_4 were observed in summer season (Figs. 2-a, 2-b, 3-a and 3-b).

Ammonia concentration showed an interesting pattern of variation. In winter, at Ras El-Hekma, Alamin, Ras Alam El-Rum and Martouh, ammonia concentrations were increased from surface down to 50 m depth and then decreased down to 100m depth. After that, in deep waters the homogeneity in concentrations was observed in deep water. In contrast, for summer season, the concentrations at all stations were decreased from surface water down to 25 m depth, and then increased down to 50 m depth. After that, more or less constant concentrations of NH_4 were recorded in deep water (Fig. 2-a). High concentrations of ammonia were found in winter with values varied from 0.25 to 8.6 µmol/l. This may suggests the occurrence of denitrification process. However, in summer season ammonia showed low concentrations ranged from 0.80 to 3.70 µmol/l. This result demonstrates that in the euphotic zone (up to 25 m depth) of Mediterranean of the west coast of Alexandria, ammonia is the preferable uptake by phytoplankton as a nitrogen source for assimilation during summer, while in winter, nitrate may support primary production more than ammonia does.

During the period of study, the water column profiles for NO_2 and NO_3 showed sharp decrease of both ions from surface down to 25 m depth, reflecting high consumption of these DIN forms by planktonic organisms. Fahmy [8] found that the surfacial water in Dabaa and Sallum area, DIN constituted a mean value of 3.81±0.53% of TN revealing the increasing consumption and deposition rates for these inorganic constituents. In winter season, NO_2 depletion was appeared in intermediate water column (50-100 m depth) at Alamin and Matrouh sections. High concentration values ranged from 0.25 to 0.48 µmol/l were observed in the intermediate and bottom water of Alamin, Dabaa, and Ras El-Hekma. In summer, vertical pattern of NO_2 variations was almost the same as in winter season, however NO_2 content was higher and its values ranged from 0.075 to 1.213 µmol/l at 25 m depth of Ras Alam El-Rum and Ras El-Hekma, respectively. These high summer concentrations of NO_2 in the intermediate and bottom waters may be reflecting dentrification process.

In winter, NO_3 levels increased rapidly (reached to 6.97 µmol/l) at 150 m depth and bottom water of Ras Alam El-Rum, Matrouh, and Sallum sections with respect to surface content. This may be attributed to the release from bottom sediment and occurrence of nitrification process as indicated by depletion and low concentrations of NO_2 of the same water layers of these sections.

$$NH_4 \underset{\text{Denitrification}}{\overset{\text{Nitrification}}{\rightleftarrows}} NO_2 \rightleftarrows NO_3$$

In summer season, the accumulation of nitrate with concentrations ranged from 5.73 to 10.76 µmol/l in the intermediate water (50-100 m depth) at almost all sections demonstrating low rate of nitrate consumption by phytoplankton. Fahmy [8] observed a diminish in phytoplankton biomass in the intermediate water (120-250 m depth) of the same area of the west coast of Alexandria. It is worth to mention that this observation came in accordance with low level of NH_4 obtained during this study at the euphoric zone in summer.

The content of PO_4-P in sea water was greatly higher in summer than in winter. The concentration values ranged from depletion to 0.95 µmol/l in winter and from 0.05 to 3.55 µmol/l in summer. The noticeable increase of phosphate particularly in the upper 50 m depth during summer resulted from increasing population due to lots of summer resort constructions along the west coast of Alexandria. According to Béthoux *et al.*,[9] the hypothesis of an influx increase from phosphate sources over the whole Mediterranean is in qualitative agreement with global scenario proposed by Meybeck[10] where total dissolved phosphorus in land surface water globally increases proportionally to the watershed population and to its energy consumption. During winter, the potential tourism decreases leading to the decrease of human activity using detergents. Consequently, low PO_4 content reached to depletion appearing in the surface water. Moreover, the depletion of PO_4 appeared also at the euphotic zone in many stations of the study area. This illustrates that phosphate ion is the limiting factor for phytoplankton growth during this season.[11]

Depletion or low level of phosphate in the intermediate and deep waters resulted from phosphate removal by adsorption on particles. High concentration of 0.45 µmol/l was obtained at 150 m depth of Alamin and Ras El-Rum sections during winter reflecting the rapidly recycling of phosphorus in deep water. Krom *et al*.,[11] reported that primary production in the eastern Mediterranean has been shown to be phosphorus limited.

Silicate behavior in the water column is more or less similar to that of nitrate (Figs. 2-b and 3-b). In winter, silicate concentrations were low and ranged from 0.90 µmol/l at 200 m depth of Ras Alam El-Rum to 4.08 µmol/l at 25 m depth of Sidi Barani (Fig. 2-b). However, obvious high concentrations of silicate were found in summer as a result of increasing land run-off and urban activities. These high values ranged from 3.18 µmol/l at 200 m depth of Sidi Barani to 20.13 µmol/l at 100 m depth of Ras El-Hekma (Fig. 3-b). During winter, silicate was consumed in the euphotic zone (25 m depth) in most stations. Enrichment of silicate observed at the intermediate water of certain stations may have resulted from dissolution and sinking of diatom frustules. Regeneration of silicate from the bottom sediment and releasing into the overlying bottom water could be the reason for high silicate content in deep water. The vertical profiles of nutrient concentrations observed in this study are opposite to the classical nutrient profiles obtained by Béthoux *et al*.,[9] at Algero-Provencal basin of the Mediterranean Sea. This study may suggest the characteristic of high eutrophication level in the euphotic zone (25-50 m depth) of the western coast of the Mediterranean Sea (Alexandria) in Egypt.

Spatial distribution: The results demonstrate the existence of spatial and seasonal variability for the Mediterranean Sea water of studied area. Seasonal changes are more pronounced than spatial variations (Fig. 4).

Generally, spatial distribution of nutrient concentrations showed slight variations among sections during summer and winter. This may be due to well mixing of water mass under the influence of prevailing wind and current regime along the coast. Sharaf El Din *et al*.,[12] mentioned that the current regime appeared at the coastal area of Mediterranean Sea (west of Alexandria) to consist of sustained periods of wind induced, easterly flow, when the dominant wind direction was from the north-west. Increasing trends for nutrient concentrations except ammonia were observed in summer season for both inshore (up to 50 m depth) and offshore (up to 200 m depth) stations. In summer, Ras El-Hekma showed the highest concentration of phosphate (1.83 µmol/l) and silicate (20.13 µmol/l) at offshore stations, while the highest concentration of ammonia (4.70 µmol/l) and nitrite (1.21 µmol/ l) appeared at its inshore stations. Sallum, Matrouh and Ras El Hekma recorded the lowest concentrations of phosphate (0.0-0.25 µmol/l) at inshore and offshore stations during winter. Generally, phosphorus concentrations are low in sea water and can limit biological productivity in some marine ecosystems.[13,14] Spatial variability of silicate was very low during both summer and winter. However, silicate content was three times (average value 5.14 µmol/l) for summer season than in winter (average value 1.85 µmol/l). Insignificant difference in nutrient concentrations appeared among inshore and offshore stations during the study period demonstrate extending effect of terrestrial inputs seawards.

These results reflect the increased population activity during summer (tourism Season) as an external source of terrestrial inputs to this area of the Mediterranean Sea. The obtained data in this study could serve for more investigation to understand the impact of the development and new constructions established along the western coast of Mediterranean Sea in Egypt (west of Alexandria).

CONCLUSIONS

1. The vertical profiles of nutrients data obtained in this study showed clearly reversed shape to the classical features of nutrients levels in the Mediterranean Sea recorded by Béthoux *et al*.[9]
2. In general, no clear differences between nutrient elements were observed among most of studied sections. This might be attributed to the influence of prevailing winds and water current regime in this region.
3. Symptoms of eutrophication were observed at the costal area of Mediterranean, west of Alexandria, whereas high enrichment in nutrient elements was achieved during the period of study. Nutrient concentrations increase is much more dependent on the terrestrial and land-run off inputs.
4. This study paid attention to the shallow 25 m depth to under investigation. The obtained data enabled to prove clearly the presence of eutrophication with nutrients in this layer. Moreover, this study added further support to recognize the load of nutrients in surface and euphotic zone after constructions along the coast.
5. Both denitrification and nitrification processes appeared in the water column of the area under investigation in summer and winter; respectively.
6. Observed low and depleted phosphate levels in this study confirmed that phosphorous, as usual, is a limiting factor for biological productivity in marine ecosystems.

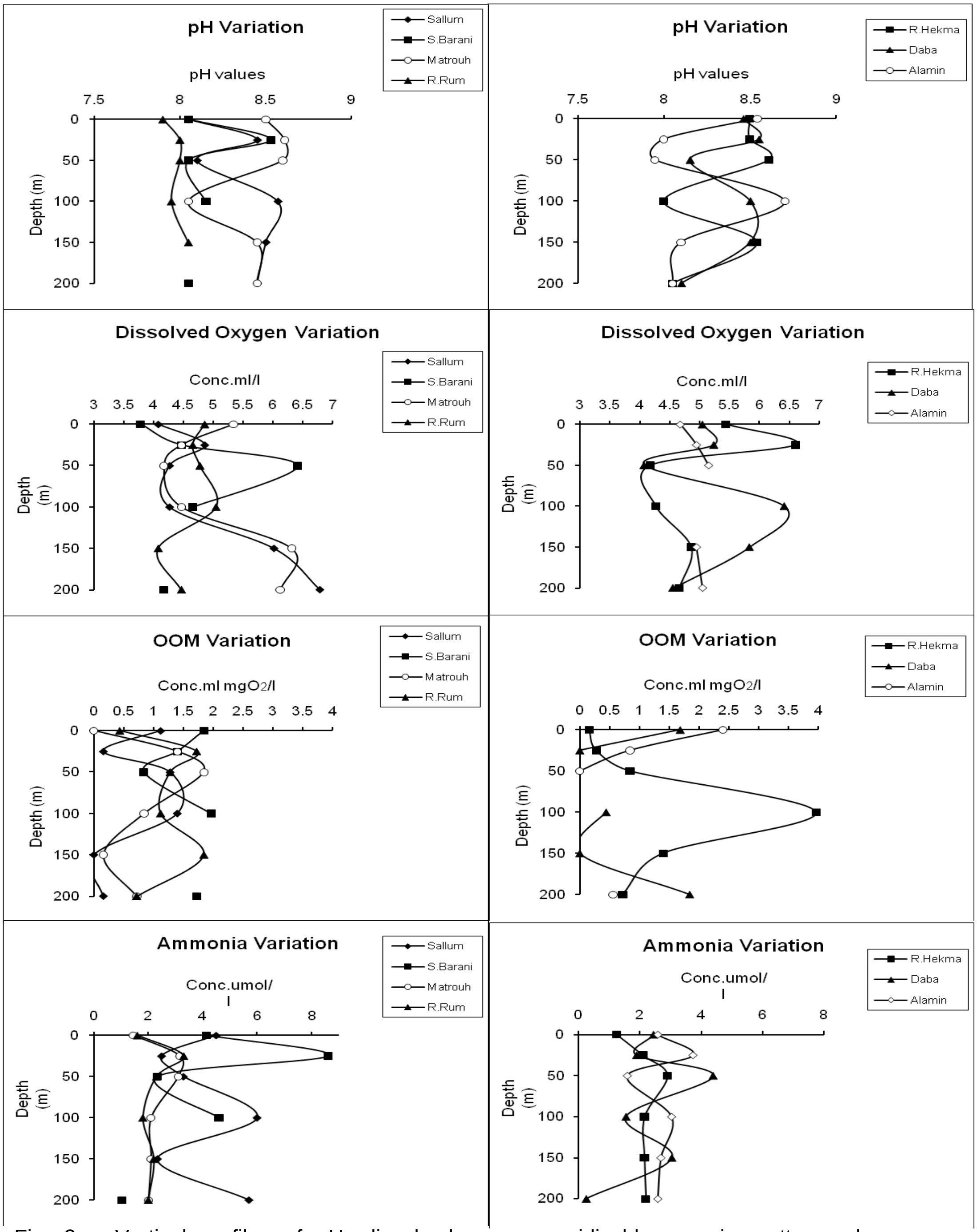

Fig. 2-a: Vertical profiles of pH, dissolved oxygen, oxidizable organic matter and ammmonia at offshore stations of different sections along the western coast of Alexandria during winter, 2006.

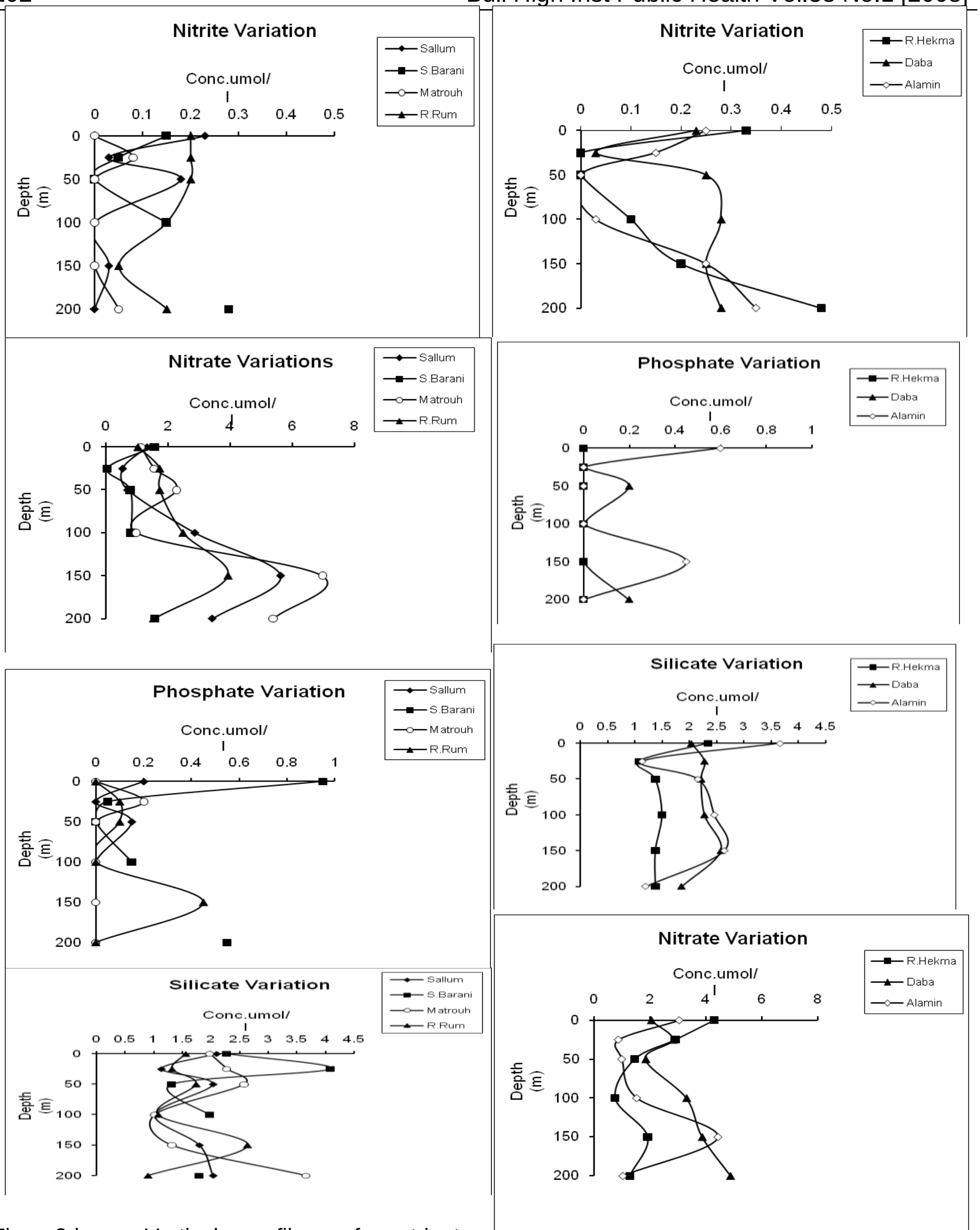

Fig. 2-b: Vertical profiles of nutrients concentrations at offshore stations of studied sections along the western coast of Alexandria during winter, 2006

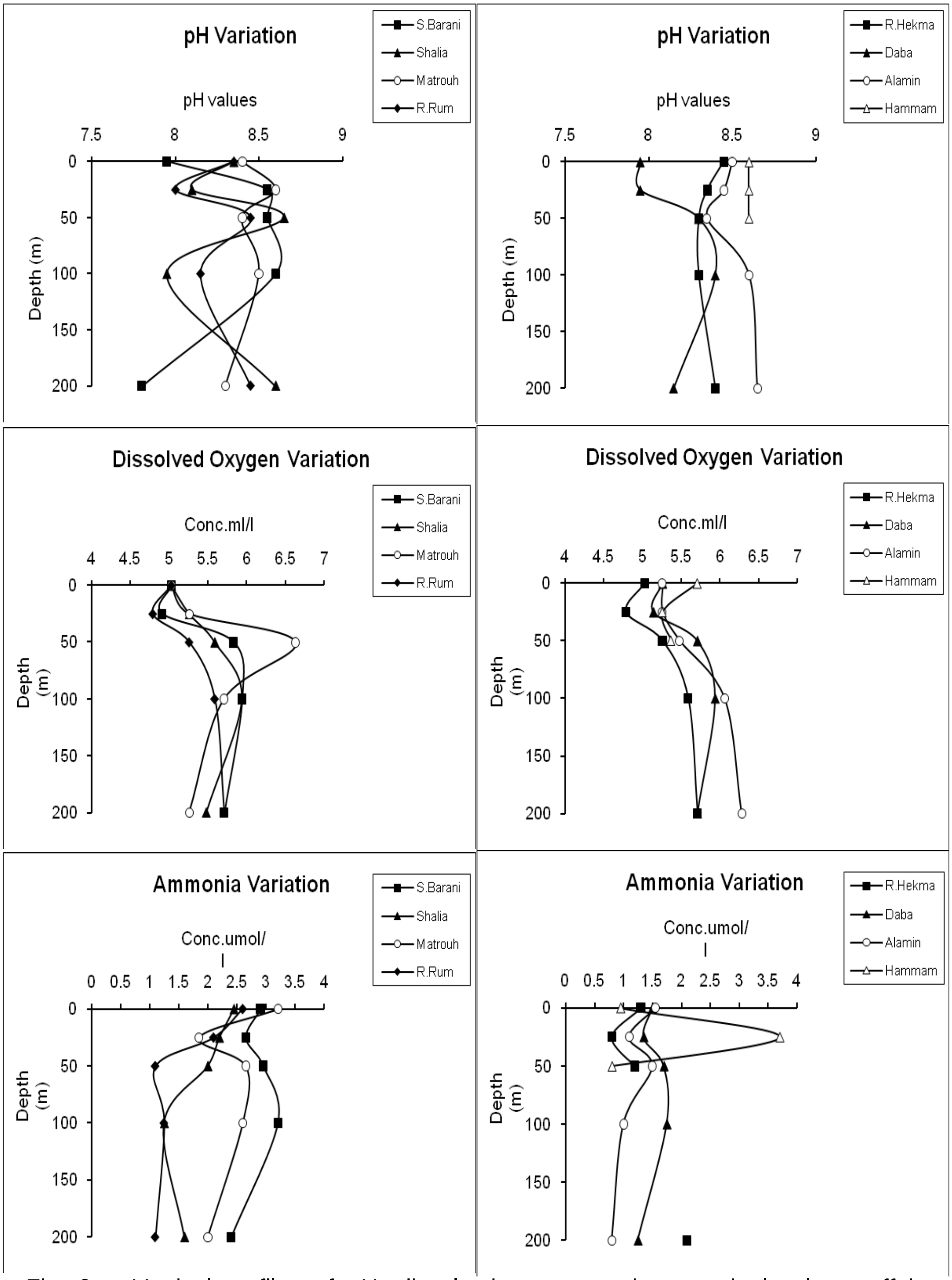

Fig. 3-a: Vertical profiles of pH, dissolved oxygen and ammonia levels at offshore stations of studied sections along the western coast of Alexandria during summer, 2006.

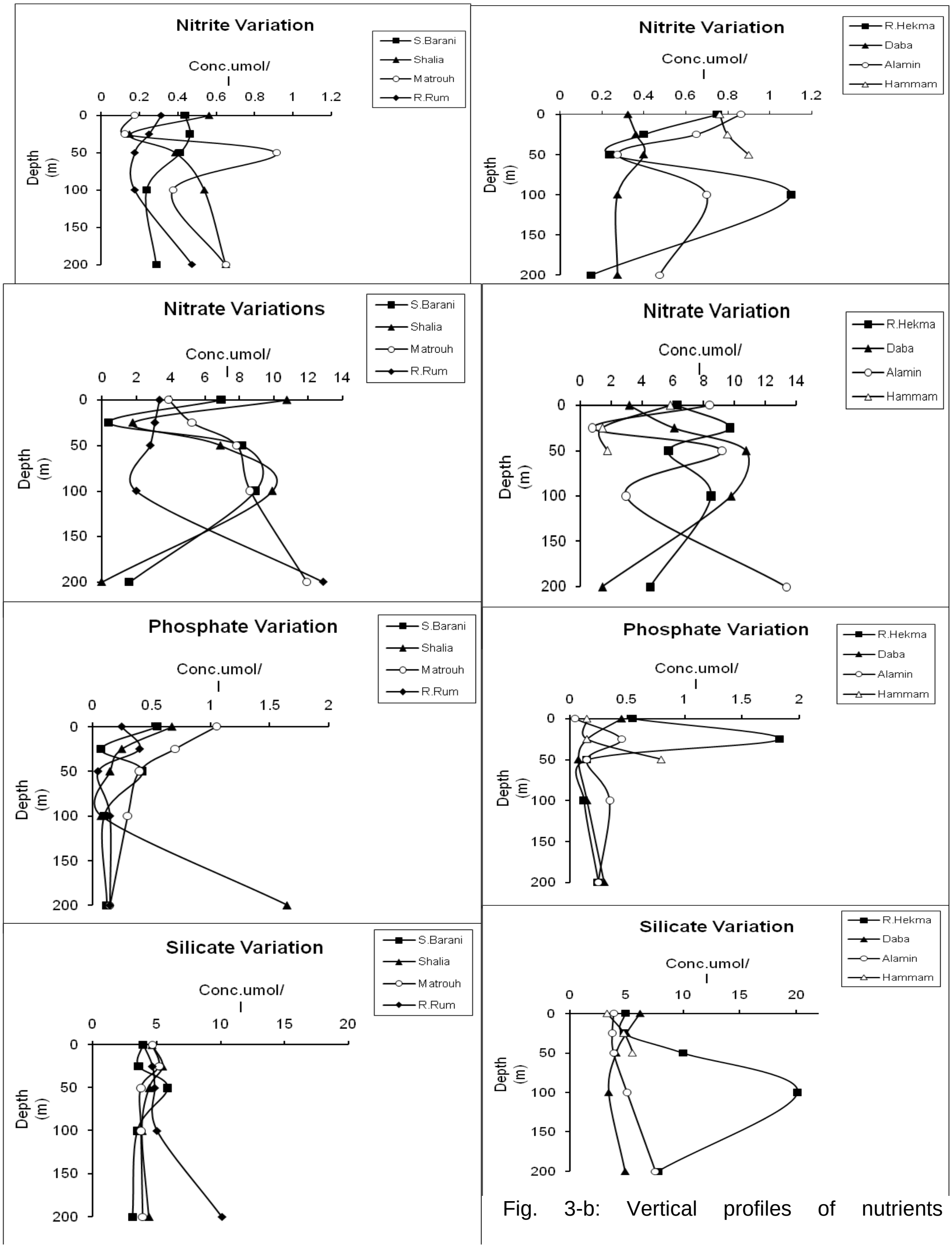

Fig. 3-b: Vertical profiles of nutrients concentrations at offshore stations of studied sections along the western coast of Alexandria during summer, 2006.

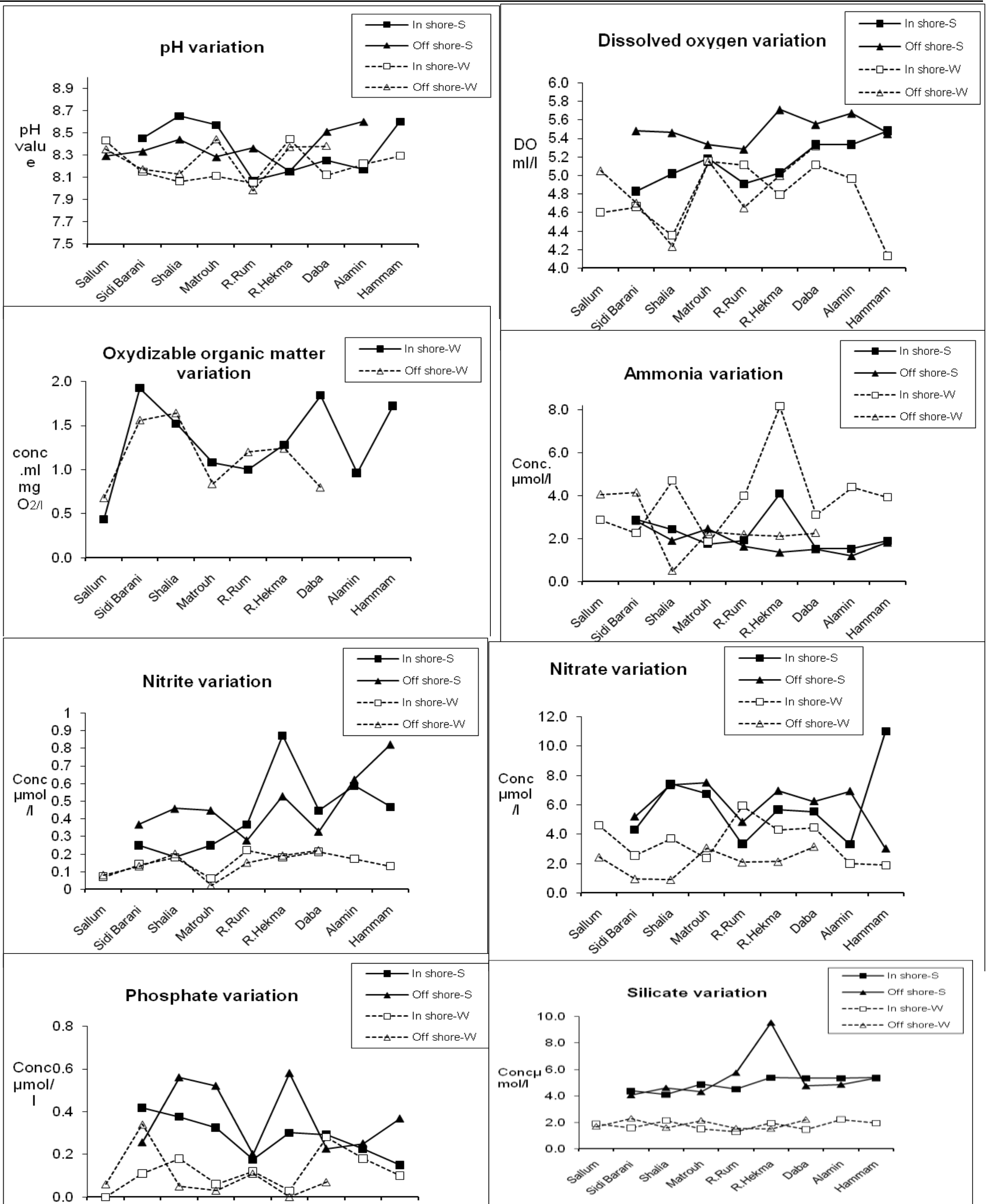

Fig. 4: Spatial distribution of pH, dissolved oxygen, oxidizable organic matter and

nutrients. concentrations at inshore and offshore stations along the western coast of Alexandria during winter and summer, 2006

Table 1a: The average values of studied parameters at inshore station of different sections of the western coast of Mediterranean Sea in Egypt (west of Alexandria) during 2006.

Sections	pH value		DO ml/l		OOM mgO2/l	NH4 µmol/l		NO2 µmol/l		NO3 µmol/l		PO4 µmol/l		SiO4 µmol/l	
	winter	summer	winter	summer	winter	winter	Summer	winter	summer	winter	summer	winter	summer	winter	summer
Sallum	8.43		4.60		0.10	2.85		1.90		4.59		0.0		1.88	
Sidi Barani	8.15	8.45	4.66	4.83	0.48	2.24	2.88	0.14	0.25	2.54	4.28	0.11	0.42	1.58	4.36
Shalia	8.06	8.45	4.35	5.02	0.38	4.69	2.43	0.18	0.18	3.70	7.43	0.18	0.38	2.13	4.09
Matrouh	8.11	8.57	5.15	5.18	0.27	1.85	1.75	0.06	0.25	2.36	6.74	0.06	0.33	1.49	4.86
Ras A.El Rum	8.05	8.07	5.11	4.91	0.25	3.97	1.92	0.22	0.37	5.92	3.32	0.12	0.18	1.28	4.50
Ras El Hekma	8.44	8.15	4.79	5.03	0.32	8.13	4.08	0.18	0.87	4.30	5.67	0.03	0.30	1.94	5.37
Dabaa	8.12	8.25	5.11	5.33	0.46	3.10	1.53	0.21	0.45	4.44	5.54	0.28	0.29	1.46	5.34
Alamin	8.22	8.17	4.96	5.33	0.24	4.38	1.53	0.17	0.59	2.00	3.31	0.18	0.23	2.21	5.34
Hammam	8.29	8.6	4.13	5.48	0.43	3.90	1.90	0.13	0.47	1.89	11.00	0.10	0.15	1.94	5.36

Table 1b: The average values of studied parameters at offshore station of different sections of the western coast of Mediterranean Sea in Egypt (west of Alexandria) during 2006.

Sections	pH value		DO ml/l		OOM mgO2/l	NH4 µmol/l		NO2 µmol/l		NO3 µmol/l		PO4 µmol/l		SiO4 µmol/l	
	winter	Summer	winter	summer	Winter	winter	summer	winter	summer	winter	summer	winter	summer	winter	summer
Sallum	8.35		5.05		0.17	4.06		0.08		2.41		0.06		1.69	
Sidi Barani	8.17	8.29	4.70	5.48	0.39	4.15	2.82	0.13	0.37	0.95	5.2	0.34	0.26	2.29	4.04
Shalia	8.13	8.33	4.23	5.46	0.41	0.50	1.90	0.20	0.46	0.89	7.35	0.05	0.56	1.59	4.60
Matrouh	8.44	8.44	5.15	5.33	0.21	2.32	2.46	0.02	0.45	3.05	7.52	0.03	0.52	2.14	4.28
Ras A.El Rum	7.98	8.28	4.65	5.28	0.30	2.20	1.63	0.15	0.28	2.07	4.83	0.11	0.20	1.54	5.74
Ras El Hekma	8.37	8.36	5.00	5.71	0.31	2.13	1.35	0.19	0.53	2.11	6.96	0.0	0.58	1.51	9.53
Dabaa	8.38	8.15	5.32	5.55	0.20	2.27	1.51	0.22	0.33	3.13	6.25	0.07	0.23	2.21	4.73
Alamin		8.51		5.67			1.19		0.62		6.93		0.25		4.84
Hammam		8.60		5.45			1.82		0.82		3.01		0.37		5.34

Table 1b: The average values of studied parameters at offshore station of different sections of the western coast of Mediterranean Sea in Egypt (west of Alexandria) during 2006.

Sections	pH value		DO ml/l		OOM mgO2/l	NH4 µmol/l		NO2 µmol/l		NO3 µmol/l		PO4 µmol/l		SiO4 µmol/l	
	winter	Summer	winter	summer	Winter	winter	summer	winter	summer	winter	summer	winter	summer	winter	summer
Sallum	8.35		5.05		0.17	4.06		0.08		2.41		0.06		1.69	
Sidi Barani	8.17	8.29	4.70	5.48	0.39	4.15	2.82	0.13	0.37	0.95	5.2	0.34	0.26	2.29	4.04
Shalia	8.13	8.33	4.23	5.46	0.41	0.50	1.90	0.20	0.46	0.89	7.35	0.05	0.56	1.59	4.60
Matrouh	8.44	8.44	5.15	5.33	0.21	2.32	2.46	0.02	0.45	3.05	7.52	0.03	0.52	2.14	4.28
Ras A.El Rum	7.98	8.28	4.65	5.28	0.30	2.20	1.63	0.15	0.28	2.07	4.83	0.11	0.20	1.54	5.74
Ras El Hekma	8.37	8.36	5.00	5.71	0.31	2.13	1.35	0.19	0.53	2.11	6.96	0.0	0.58	1.51	9.53
Dabaa	8.38	8.15	5.32	5.55	0.20	2.27	1.51	0.22	0.33	3.13	6.25	0.07	0.23	2.21	4.73
Alamin		8.51		5.67			1.19		0.62		6.93		0.25		4.84
Hammam		8.60		5.45			1.82		0.82		3.01		0.37		5.34

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