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Phytoplankton in polluted waters of the Red Sea coast of Yemen

*Akram Alkershi and [1]N. Nandini Menon

*Department of Earth and Environmental Sciences, Faculty of Sciences, Sana'a University, Sana'a, Yemen. E-mail: alkershi111@yahoo.com

[1]Nansen Environmental Research Centre, Gopal Residency II Floor, Thottekkat Road, Cochin-682 011, Kerala, India

Abstract

Surface water samples were collected in March 2009 from five selected stations (between 14° 46.851′ to 15° 26.851′ N and 42° 54.850′ to 42° 57.138′ E) in the coastal waters of the Yemeni Red Sea. The coastal waters of Al-Hodeidah is highly polluted and eutrophicated causing regular blooms of the dinoflagellate *Noctiluca miliaris*. The effect of pollution was reflected on phytoplankton abundance and species diversity in the sewage-fed area, north of Al-Hodeidah. The non-polluted coastal waters off Al-Saleef supported rich phytoplankton coupled with high species diversity and richness. No signs of temperature-influenced floral disturbance were noticed in the coastal waters which received thermal effluents from a steam power station at Ras Al-Katheeb.

Keywords: Microalgae, blooms, pollution, species diversity

Introduction

Phytoplankton studies in the Red Sea are very few, and only a few coastal surveys have been made so far. No detailed account on phytoplankton distribution and productivity is available from the Red Sea coast of Yemen. The available data are documented in the reports of IUCN (1987) and Rushdi *et al.* (1994). Phytoplankters are critical food for filter-feeding bivalves as well as for the larvae of commercially important crustaceans and finfishes. However, in some situations microalgal blooms can have a negative effect, causing severe economic loss to aquaculture, fisheries and tourism operations, and also have major environmental and human health impacts. Microalgal blooms appear to be stimulated mainly by the discharge of large quantities of nutrients from domestic, industrial and agricultural wastes to the coastal waters of Yemen. Frequent microalgal blooms occur with increasing discharge of nutrients through human activities. In Hong Kong harbour during 1976 to 1986, there was an 8-fold increase in the number of red tides per year (Lam and Ho, 1989), showing a striking relationship with a 6-fold increase in human population, and concurrent 2.5 fold increase in nutrient loading, mainly contributed by untreated domestic and industrial wastes. A similar phenomenon was noticed in Seto Inland Sea in Japan (Okaichi, 1989), where between 1965 and 1976 the red tide outbreaks progressively increased 7-fold, concurrent with a 2-fold increase in the COD loading, mainly from untreated sewage and industrial waste from pulp and paper factories. In the Indian coastal waters, harmful algal blooms have increased in frequency, intensity and geographic distribution in the last two decades (Padmakumar *et al.*, 2009).

The phenomenon of red tide in coastal waters was rarely seen in Yemen in the past few decades. But the occurrence of red tide in the Red Sea and Gulf of Aden Yemeni coastal waters have increased drastically in the last few years. This could be attributed to the increased population densities in the coastal cities and increase in discharge of wastes into the coastal waters. Although there are many reports on the increased frequency and spatial extent of microalgal blooms in the Yemeni waters, no detailed study on the causes, impacts, control measures and management have been carried out so far.

The aim of this study was to investigate phytoplankton species composition and abundance along with the hydrographic parameters in polluted waters to identify the causative agents, which may trigger microalgal blooms; and to suggest control measures for management of coastal waters in Yemen.

Material and Methods

Surface water samples were collected on the 3rd and 4th of March 2009 from five selected stations distributed between Lat. 14° 46.851′ - 15° 26.851′ N, and Long. 42° 54.850′ - 42° 57.138′ E in the Red Sea (Fig. 1). The samples were collected in 5 L capacity plastic containers and preserved using Lugol's iodine solution and kept for 72 hrs to allow complete settlement of planktonic algae. The clear surface layer was siphoned out, and the remaining sample was transferred into a measuring cylinder of 1 L capacity and kept for another 72 hrs to allow complete settlement of the microalgae. The clear surface layer was siphoned out, so as to concentrate the sample to 50 ml. The settled planktonic algae were examined and identified using a microscope (Nikon SMZ 1500) employing standard keys. Planktonic algae were enumerated using a Sedgwick-Rafter counting cell. Water temperature and salinity were measured at each station using a calibrated thermometer and a standardised salinometer. The concentration of dissolved inorganic phosphate in

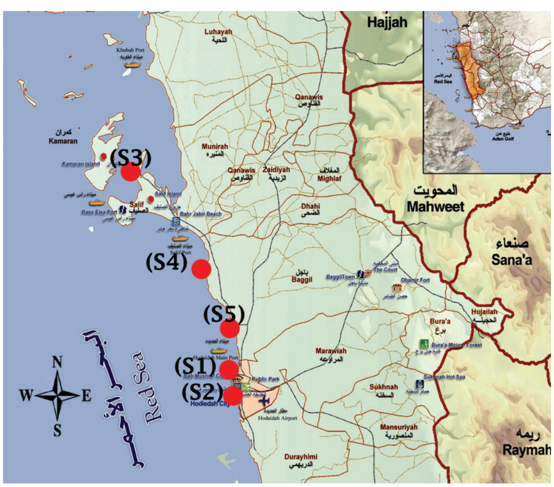

Fig. 1. Location map showing sampling stations in the Red Sea

seawater at each station was determined using a spectrophotometer by adopting the method of Murphy and Riley (1962) modified by Koroleff (1983). Nitrite concentration was determined by Bendschneider and Robinson (1952) method. Nitrate was reduced to nitrite (Grasshoff, 1983) and estimated using a spectrophotometer.

Results and Discussion

Red Sea ecosystem has many unique features - it is small sized, almost completely landlocked, has a slow turnover rate of six years for the surface water layer and 200 years for the whole water body (Sheppard *et al*., 1992). These features, along with its complex reefs, extensive mangroves, seagrass and macro-algal beds form highly productive habitats for unique species assemblages. Endemism is very high in the Red Sea Large Marine Ecosystem (LME), among dinoflagellates, euphausiids and reef fishes (Getahun, 1998).

At station 1, the coastal waters of Al-Hodeidah, where domestic wastes are discharged, the phytoplankton population was composed of 11 species of diatoms, 3 species of dinoflagellates and one species of silicoflagellate (*Dictyocha fibula*). Among the sampling sites, maximum salinity was recorded at this station. The dominant species was *Noctiluca miliaris* (Table 1) contributing about 85 % of the total cell count. It has been noticed that even though *N. miliaris* forms blooms in the region, it does not adversely affect the diversity of phytoplankton in the region.

Station 2, near the fish landing center at Al-Hodeidah, is polluted due to the discharge of large quantities of remains of slaughtered fishes and wastes from fishing boats. Dense bloom of *N. miliaris*, with a cell count of $5.5 \times 10^5 / L^{-1}$ was recorded at this station (Fig. 2). The density of *N. miliaris* was so high that co-existing phytoplankton species were reduced to insignificant numbers. However, mass mortality of marine organisms, as reported along the southwest coast of India, (Sarangi and Mohammed, 2009) where bloom of *Noctiluca* occurred in September 2002 was not observed. In the coastal areas of Gulf of Mannar (southeast coast of India) also, intense bloom of *Noctiluca* was associated with

Table 1. Planktonic algal concentrations (number of cells per litre) in 5 stations of Red Sea coast of Yemen

Species	Station 1	Station 2	Station 3	Station 4	Station 5
Diatoms					
Coscinodiscus sp.	M			M	
C. bouvet				M	
Navicula granii	100		250	50	M
N. transitrans var. derasa	M				50
N. distans			150	200	
N. clementis					300
Nitzschia longissima	M		50	150	150
Nitzschia sp.					200
Odontella aurita				50	
Plagiotropis gaussii	50				
Pleurosigma normanii	50		50	100	150
P. directum					M
Rhizosolenia setigera	M				M
R. bergonii			50		
Thalassionema nitzschoides	M		50	M	
T. frauenfeldii	150		150		
Thalassiosira bulbosa	50			M	
Thalassiothrix longissima	M		200	50	50
Diploneis weissflogii			50		
Climacosphenia moniligera				500	
Licmophora abbreviata				2350	
Skeletonema costatum				19,000	
Dinoflagellates					
Ceratium furca			150		
C. fusus			50		
Noctiluca miliaris	4400	5,50,000	150		
Dinophysis acuminata			50		
Peridinium oblongum	150				
P. depressum			M		
P. pallidum				250	
Prorocentrum micans	200		950		
P. minimum			100		
Gonyaulax diegensis			M		
Heteraulacus acuminatus			M		
Silicoflagellates					
Dictyocha fibula	50		50		
Bluegreen algae					
Arthrospira massartii			M		
Oscillatoria sp.			550	50	
Haptophyte					
Phaeocystis globosa				M	
TOTAL	5.2×10^3	5.5×10^5	3.05×10^3	2.275×10^3	9×10^2

M <10/L

dead fishes, molluscs, crabs, jellyfishes, sea anemones, sea cucumbers and polychaetes in October 2008 (Gopakumar *et al.*, 2009). Mohamed and Mesaad (2007) reported that the cell number of *N. scintillans* was negatively correlated with nitrate, phosphate and silicate concentrations (r = –0.5 to –0.97),

Fig. 2. Dense bloom of *Noctiluca miliaris* in the fish landing center at Al-Hodeidah

but positively correlated with the ammonium concentration (r = 0.9). In the present study also, the concentrations of nitrite and nitrate were low in stations 1 and 2 where *N. miliaris* bloom was observed. Mohamed and Mesaad (2007) also observed that the cell number of *N. scintillans* correlated negatively with the cell numbers of the diatom *Thalassiosira rotula,* the green alga *Dunaliella tertiolecta*, and all the dinoflagellate species (*Alexandrium* sp., *Ceratium* sp., *Dinophysis* sp., *Prorocentrum* sp.) (r = –0.4 to –0.99). These species were abundant in the absence of *N. scintillans* bloom, but their densities decreased sharply upon the appearance of *N. scintillans* bloom. The result of the present study also corroborates this view. *Dinophysis, Prorocentrum, Ceratium* and *Thalassionema,* which were abundant in Station 1, were not detected in station 2 due to the preponderance of *N. miliaris*. Bloom of *Noctiluca*, which is a mixotroph, can be indirectly linked to increasing eutrophication by an increase in prey abundance (Padmakumar *et al*., 2010).

Station 3, the coastal waters of Al-Saleef, with minimum anthropogenic influence was considered as a reference station. Maximum diversity of phytoplankton was recorded at this station, with 9 species of diatoms, 9 species of dinoflagellates, 2 species of blue-green algae and one silicoflagellate species. Here, not only the species diversity was high, but there was also specific balance among the dominant groups of planktonic algae (9 species of diatoms and 9 species of dinoflagellates). Here the planktonic abundance was intermediate (3.05×10^3 / L^{-1}) and the major contribution was made by *Prorocentrum micans* (31%) and *Oscillatoria* sp. (18 %) among the total cell number. N:P ratio at this station was found to be near the Redfield ratio, which is ideal for phytoplankton growth (Howarth, 1988). Optimum concentration of nutrients (Table 2) and favourable environmental conditions are the factors responsible for maximum species diversity at this station.

Station 4, in the area of cooling water discharge of the steam power station, Ras Al-Katheeb, had 13 species of diatoms, one species each of dinoflagellate, haptophyte and blue green alga (Table 1). The dominant species was the diatom *Skeletonema costatum,* contributing 84% of the total count of planktonic microalgae. Primary producers are affected by warm water resulting in a short life span and overpopulation of species (Straughan, 1980). Increasing temperature enhances the metabolic rates of algal cells and growth rate of phytoplankton species (Schoemann *et al*., 2005). In the present study, at station 4 the temperature of the discharged water is almost the same as that of the surrounding region. Even then, the temperature recorded was the highest (31°C) at this station, enhancing the growth rate of algae resulting in high population density. But the water appeared to be totally deprived of nutrients (nitrite: 0.03μmol/l; nitrate: 0.6 μmol/l; phosphate: 0.00 μmol/l). Similar phenomenon was noticed by Touliabah *et al*. (2010) in their studies on phytoplankton in the coastal waters off Jeddah (Saudi Arabia) during spring season, where the nitrate concentration showed lowest value and the total phytoplankton standing crop recorded the highest quantity. They pointed out that, the decrease in nitrate contents might be due to its utilization by phytoplankton. It could be inferred from the present study that there was no adverse temperature effects, although this station received thermal effluents. Presence of 16 species of phytoplankton with relatively high density and absence of dead marine organisms indicates lack of any negative thermal influence. Thermal pollution is more obvious at higher latitudes (temperate regions) where thermal

Table 2. The hydrographic parameters at five stations in the Red Sea

Stations	T (°C)	S (psu)	Phosphate (µmol/L)	Nitrite (µmol/L)	Nitrate (µmol/L)
S1	27	36	6.00	0.19	1.71
S2	26	26	49.29	0.16	5.47
S3	26	35	0.27	0.18	3.90
S4	31	35	0.00	0.03	0.60
S5	31	29	17.11	1.83	8.30

differences between the discharged cooling waters and surrounding seawater are much larger.

At Station 5, which was located in the sewage discharge area of north of Al-Hodeidah, only 9 species of diatoms were found without any significant dominance. The total count was also low at this station amounted to 9×10^2 cells / L^{-1}; (Table 1). The reason for the occurrence of less number of species at this station could be attributed to the effect of sewage pollution, which was visible in the form of white-brownish foam along the shoreline, high turbidity and associated bad odour. The low saline waters (29 psu) of station 5 recorded an abnormal N:P ratio (inorganic phosphate 17.11 µ mol / L^{-1}; nitrite 1.83 µ mol / L^{-1}; nitrate 8.30 µ mol / L^{-1}). The repeated addition of freshwater with domestic waste also would have resulted in the declension of typical marine phytoplankton.

In the present study, a direct relation could not be ascertained between the physico-chemical parameters like temperature, salinity and nutrients with phytoplankton composition or density. Culture studies have established that internal cellular concentration of nutrients determine phytoplankton growth rates, and these studies have shown that it is often difficult to relate growth rates to external concentrations, especially in natural situations (Hecky and Kilham, 1988). This should lead to a greater reliance on the composition of particulate matter and biomass-based physiological rates to infer nutrient limitation. Further, nutrient budget estimates of marine systems are difficult since they are large and lack defined hydrological boundaries. This is juxtaposed to freshwater conditions, where the water bodies are relatively well defined. Consequently, in the marine environment the paucity of data severely restricts statistical treatment of nutrient supply relationships and investigation of modifying factors such as water residence time.

Pollution from various non-point sources are seen to trigger algal blooms and upset the normal phytoplankton composition of the study area. The pollution abatement facilities like the sewage and domestic waste treatment at Al-Hodeidah are inefficient, resulting in indiscriminate discharge of wastes into the coastal waters of Red Sea. In conclusion, the results of our study, along with those of previous studies (Painting *et al.*, 1993; Hayward *et al.*, 1995), highlight the need for regular monitoring of blooms of potentially harmful algae and the physico-chemical parameters in the coastal waters of Red Sea in order to discover the factors triggering harmful algal blooms.

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