Distribution of Biochemical Oceanography in the Bay of Bengal: A Review

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Abstract

A study was carried out to look into different biological and chemical parameters in the Bay of Bengal (BoB) from previous papers. In general, BoB water has some unique characteristics compared to the Arabian sea (AS) attributes. Because of large freshwater influx and weak wind induced mixing of water column, BoB has less saline water compared to AS. Apart from these physical phenomena, BoB have been poorly investigated before to compare with its bio-chemical traits. Keeping that in mind, we are presenting here some of the bio-chemical features of BoB. In the present findings, among the metals concentration, Ca (Calcium) was found to be the higher, while Ti (Titanium) was the lowest among the collected data of the major and trace elements in the sediments of the BoB. The C_{org}/N (atomic ratio) values of the sediments showed a wide depth variation. Among the nutrients (Nitrate, Nitrite, Phosphate, Ammonia and Silica), Ammonia was in higher concentration compared to rest of the nutrients. There were considerable variations in primary productivity and chlorophyll concentration in the surface layer of water, whereas, these were found to be constant in greater depths. However, vertical line of chlorophyll and productivity change revealed the correlation between them. It would be suggested that as BoB region has poorer oceanographic data to make comparison among different parameters, further investigations should need to be conducted to collect and analyze in-situ bio-chemical data in a greater extent.

Keywords: BoB, Trace element, Nutrients, Particulate Organic Carbon, Chlorophyll, Productivity.

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Introductions

Phytoplankton is the primary food producer in the ocean and photosynthesis is the key production process of food for consumer such as zooplankton. Organisms in the higher food chain then take these zooplankton as their food source. Generally, among the nutrients present in seawater, a minute quantity is required by the living organisms. Nutrients are essential for enhancing the growth of phytoplankton or primary producer. The phytoplankton cells take the nutrients and built them as atoms in amino acids, proteins, nucleic acids, fats, etc. In particular, among the nutrient elements, silicate is essential to build-up the skeleton of diatoms consisting of biogenic silicate (Becker et al., 1998). Marine bacteria decompose the dead part of phytoplankton, zooplankton or higher organisms. In turn, this comes in a particle and dissolved form of nutrient, so that it can easily be taken by phytoplankton. Nutrients distribution is more useful for the abundance and assemblages of phytoplankton. To predict productivity, nutrient distribution can be used as an indicator or the status of nutrients at a particular region (De-Pauw and Naessens, 1991). In the marine environment, nitrogen, phosphorus and silicon cycles play very important roles in controlling important nutrients. For example, the availability of nitrogenous nutrients and biological productivity in marine systems is controlled by nitrogen cycle (Ryther and Dunstan, 1971). Carbon cycle is one of the important parts in ocean that directly linked with the fixation of atmospheric carbon dioxide and export of carbon from the ocean's surface (Falkowski et al., 1998). Primary production, species distribution and ecosystem structure are regulated by the availability of phosphorus through phosphorus cycle. Phosphate availability is considered as the proximal macronutrient in some marine and estuarine environments that can limit primary production (Paytan and McLaughlin, 2007). The Bay of Bengal (BoB) is sometimes compared to its western counterpart, the AS, because BoB is considered to have poorer biological productivity (Madhupratap et al., 2003). Although, in BoB there have enormous nutrient source from the riverine flux, but because of its narrow shelf they are thought to be lost to the deep (Qasim, 1977; SenGupta et al., 1977; Radhakrishna et al., 1978). Another reason for this poor productivity is heavy cloud in the BoB area (Madhupratap et al., 2003). It is well known that weather condition of BoB area is cloudy to a great extent. The sunlight which is the most necessary element to produce the phytoplankton can be blocked by the presence of cloud. However, BoB is generally known as a cyclone-prone region and these types of events churn-up the area, injecting nutrients to the shallow euphotic zone and thereby enhancing production in the upper layers (Madhupratap et al., 2003). Particulate Organic Carbon (POC) is another important parameter for increasing biological production. However, little data about POC distribution in BoB waters were previously recorded and they were restricted to the euphotic zone only (Radhakrishna 1978; Radhakrishna et al., 1978; Bhattathiri et al., 1980). Apart from this, temperature in the deep ocean plays a significant role in determining the distribution of biogeochemical properties of the ocean. In an earlier study, Sarma et al., 2001, reported that, there exists a difference of about 2^0C in the temperature between the BoB and Andaman Sea at 2,000 m depth. This dissimilarity can attribute to difference in bio-chemical properties between these two-water body. In this study, we have overviewed bio-chemical parameters such as carbon, nitrogen, POC, chlorophyll, productivity, some major and trace elements in the BoB from several literatures to give readers of this paper a general idea on the distribution of these parameters in this marine ecosystem.

Materials and methods

As there have been no complete data available in the field of bio-chemical oceanography over the entire BoB, a number of previously published papers was reviewed during this study to collect data on different kinds of biological and chemical parameters over different areas of the Bay of Bengal.

Results and Discussion

Major and trace element in sediment

"Among the concentrations of major and trace elements in the sediments of the western BoB, Sodium (Na) was varied from 0.54 to 2.39 wt%, Potassium (K) from 1.03 to 3.08 wt%, Calcium (Ca) from 0.74 to 29.37 wt%, Magnesium (Mg) from 0.80 to 3.39 wt%, Aluminum (Al) from 2.50 to 9.19 wt%, Iron (Fe) from 1.84 to 6.54 wt%, Titanium (Ti) from 0.16 to 0.57 wt% and Manganese (Mn) from 0.03 to 1.09 wt%, respectively (Tripathy et al., 2014)." Among all the elements, Ca showed the highest variation in the sediment sample, while Ti had the least variation. Predominantly, western BoB sediments are supplied by the major rivers draining systems from the Himalayas (e.g., the Brahamaputra and the Ganga) and the peninsular India (e.g., the Godavari, the Krishna and the Mahanadi) (Tripathy et al., 2014). Presently, these rivers along provide 1350 million plenty of sediments per annum to the BoB, that accounts for ~8% of the total riverine supply to the oceans (Milliman and Syvitski, 1992; Milliman, 2001). From the reference study of Tripathy et al., 2014, average total nitrogen value was found to be 0.1 wt%. The atomic ration of CN as (C_{org}/N) of the sediments showed a wide depth variation starting from 1.1 to 26.3, (only excluding two anomalous samples) with a mean value of 12 ± 4. All these measured parameters including carbonate ($CaCo_3$), C_{org}, C_{org}/N, exhibited great variations in relation with depth (Fig. 1).

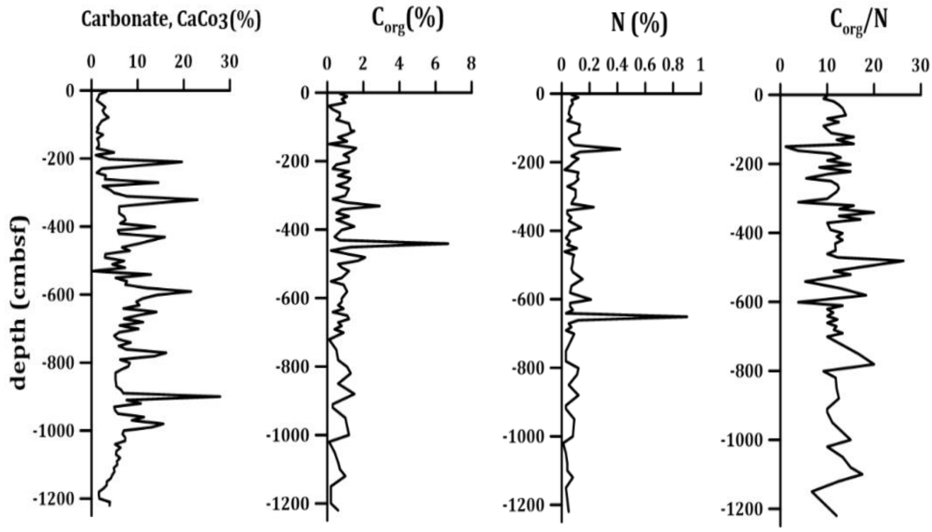

Figure 1: Depth profile of carbonate, C_{org}, N and C_{org}/N of the sediments in the western BoB. (Source: Tripathy et al., 2014).

Time series variation of major nutrients

Large variation in the concentration of ammonium nitrogen with depth was observed and shown in Table 1. The concentration of ammonium nitrogen was varied from 0.026 to 23.52 µM and the highest value was observed on 18^{th} February 2013 (Table 1). However, concentration range didn't vary to a greater extent and was slightly similar in the date of 16^{th}, 17^{th} and 18^{th} February 2013. Differences of ammonium nitrogen concentration in the bottom and surface waters were high with respective depth. Nitrite concentrations in the study area were varied from 0.018 to 0.41 µM. The nitrite in the lower reaches showed the lowest value (0.018 µM) on the 14^{th} and 17^{th} February 2013 and the highest (0.41 µM) on 18^{th} February 2013 (Table 1). Surface nitrite concentrations were observed to be very low in this region. The nitrate in the upper reaches showed the lowest concentration (0.026 µM) on the 14^{th} and 15^{th} February 2013 and the highest (4.46µM) on 14^{th} February 2013 (Table 1). Subsurface levels showed lower nitrate concentration than those at the bottom and surface levels. The nitrate in the lower reaches showed the lowest concentration (0.026 µM) on the 14^{th} February 2013, while the value was the highest (4.46 µM) on the 14^{th} February 2013.

Table 1: Variations of nutrients concentration (µM) (Source: Seetharam et al., 2014)

Date	Depth (m)	Parameters				
		Ammonia	Nitrite	Nitrate	Phosphate	Silicate
14-2-2013	0	0.026-14.46	0.018-0.11	0.026-4.46	0.18-1.27	0.80-20.31
15-2-2013	5	0.052-22.59	0.037-0.11	0.026-0.61	0.18-7.00	0.37-10.45
16-2-2013	10	0.026-0.23	0.037-0.28	0.053-0.34	0.18-1.17	0.64-13.02
17-2-2013	15	0.026-22.51	0.018-0.22	0.053-0.45	0.22-1.17	0.85-5.96
18-2-2013	25	0.026-23.52	0.037-0.41	0.053-0.56	0.22-1.17	0.37-16.77

Highest concentration of phosphate (7.00 µM) in the interface waters was noticed on 15th February 2013. In contrast to silicate and nitrate, the phosphate levels were observed to be low in the bottom layer. Silicate concentration in the study zone at different depth varied from 0.37 to 20.31 µM (Table 1). Among the five nutrient contents studied, silicate showed more pronounced variability than ammonium, nitrate, nitrite and phosphate. Lower values of silicate concentrations were recorded on 15th and 18th February 2013. Silicate in the upper reaches was the lowest (0.37 µM) on 15th February 2013 and the highest (20.31 µM) on the 14th February 2013. However, it varied from 0.37 to 16.77 µM at 25 m depth in the lower reaches. Among all the nutrients at different depth interval, phosphate was found to be in the lowest concentration and least variations.

Primary productivity patterns in central and western BoB

Chlorophyll (chl-a) content was poor (0.06–0.28 mgm^{-3}) in open waters and 0.06–0.16 mgm^{-3} towards the coast (Fig. 2a and 2b). A subsurface chlorophyll maximum (SCM) was encountered at most stations (Fig. 2a and 2b), usually below the mixed layer A decrease in chl- a with depth in the upper layers was observed only in the northernmost open-ocean station (20N), where it was uniformly 0.28 mgm^{-3} down up to 10 m of depth. It might be due to the fact that the low salinity associated with a virtually non-existent mixed layer caused this. No clear differences were found between open and coastal waters, except the 20% of chl-a that occurred below 80 m compared to 13% in open waters (Fig.2). Column-integrated primary productivity was between 90 and 220 mg Cm^{-2}d^{-1} along 88^{0} E, but higher range was obtained along the coastal transects.

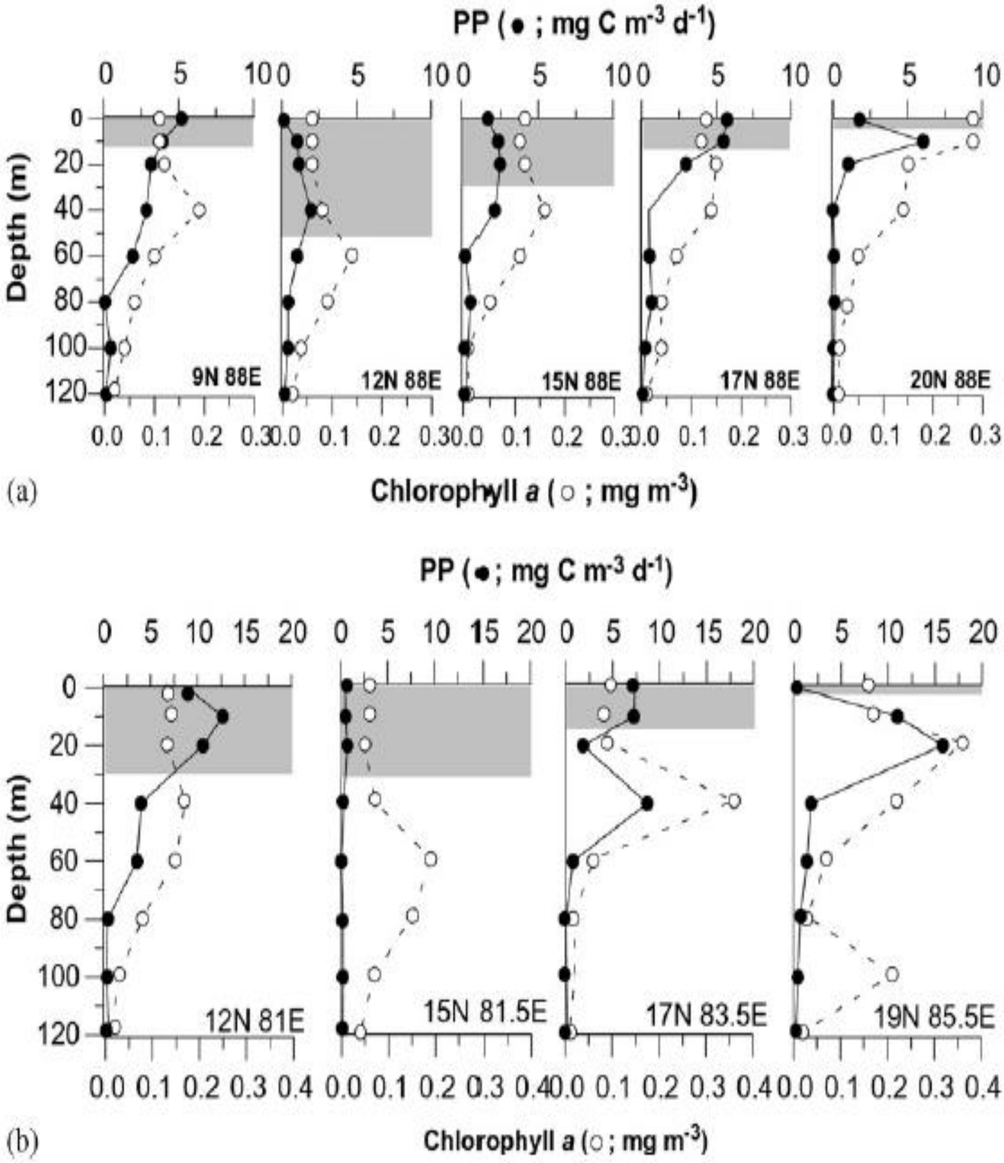

Figure 2: Vertical profiles of primary production (solid circles) and chl a (open circles) in (a) oceanic (b) coastal stations (shown by latitude and longitude). Shaded areas are shown as mixed-layer depths (Source: Madhupratap et al., 2003)

POC (Particulate organic carbon) in the Bay of Bengal

In the upper 100 water column, POC concentrations were ranged from 80 to 895 μgl^{-1}, whereas the mean values varied between 390 and 600 μgl^{-1} (Fig.3). These values are in the same range as those reported earlier (Radhakrishna, 1978; Radhakrishna et al., 1978; Bhattathiri et al., 1980). The mean surface concentration of POC was decreased regularly with increasing depth up to 2000 m (Fig. 3). At 2000 m, these values were varied from 171 to 261 μgl^{-1}, whereas the mean value was about 250 μgl^{-1}. A single observation at 3000 m showed a small increase in POC concentration (Fig. 3).

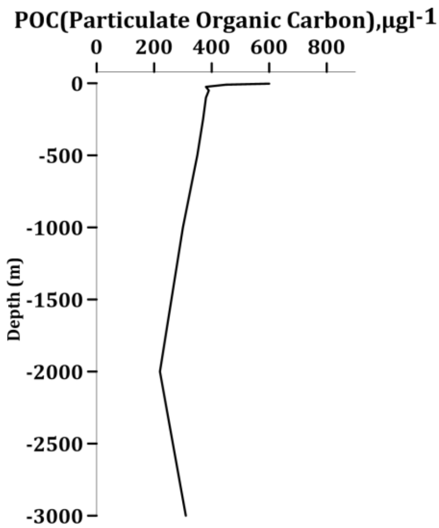

Figure 3: Depth profile of POC concentration from the oceanic waters of the Bay of Bengal. Vertical line graph is indicating mean value of POC at each corresponding depth. (source: Nandakumar et al., 1987).

Throughout the various depths of the water column, POC distribution showed large variations in all the stations, which were similar to those reported for other oceanic regions (Gordon et al., 1979). Such spatial differences of POC could be either sourced due to variations in the surface primary production or allochthonous organic matter (materials that does not come from outer source rather produce in the ocean itself) inputs at these stations. Despite of these large variations, POC concentration decreased with increasing depth at all the stations (Fig. 3). A considerable difference of opinion has arisen regarding the distribution of POC in the deep waters. Menzel (1974), concluded that the distribution of POC in deep waters is homogeneous in depth, time and space.

Table 2: Water masses and POC in the Bay of Bengal.

Watermass	Depth (m)	Salinity (‰)	Temperature (°C)	n*	Mean POC $\mu g\ l^{-1}$ (Range)
Bay of Bengal subtropical water	0-100	31.22-35.04	20.50-29.16	45	443.57 ± 160 (80.1-895.85)
A mixture of Persian Gulf and Red Sea Water	250-1000	34.98-35.09	6.48-13.24	18	270.68 ± 89 (131.8-436.5)
Indian Ocean deep and bottom water	>1000	34.74-34.8	1.61-2.87	5	262.83 ± 55 (171.4-361.7)

*Number of samples (Source: Nandakumar et al., 1987)

Concentration of the POC values found in the Bay of Bengal were comparatively high than those reported from other seas and oceans (Menzel, 1974; Wangersky, 1976; Gordon, 1977; Gordon and Cranford, 1985). Higher values of POC were expected because surface primary production was comparatively high in the Bay of Bengal (Qasim, 1977). Moreover, through the various geological formations of Indian subcontinent mainly by six rivers, larger amount of suspended organic matters is introduced into the Bay (Rao, 1985). Distribution of high amount of organic matter and primary production are probably responsible for the higher values of POC that observed here.

Conclusion

The Arabian Sea (AS) and the Bay of Bengal (BoB) are twin seas caressing the western and eastern borders of the Indian subcontinent. Surface production and other biological features of the AS are more pronounced quantitatively than in the BoB, although both the basins experience similar atmospheric forcing. In this review, sediments of western BoB were found to be rich in Ca (calcium) concentration, whereas, it may be an indication of abundance of biological organisms those are bearing calcium deposited shell. Furthermore, sediments were also abundant in organic carbon (C_{org},) and CN ratio, while nitrogen was in lower magnitude. Profuse of organic carbon in sediments may an indication of the generous of more organic matter over western BoB. In relation with this, BoB water was found to have wider variation in POC ranges from surface to a greater depth of water column. However, it was much lower in Persian Gulf and Red Sea water. Among the review of five nutrients, silicate and ammonia was in higher accumulation. Chl-a content was poor in open water of BoB, besides column integrated productivity was higher along coastal transect. As there are still lack of the oceanographic data to compare with different parameters, further studies should need to be conducted to collect and analyze in-situ biochemical data in the entire BoB region.

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