

Non-conservative Controls on Distribution of Dissolved Silicate in Cochin Backwaters

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Abstract

Cochin backwater system was studied with regard to dissolved silicate (DSi) to understand its seasonal distribution and behaviour during estuarine mixing. Silicate had a linear relationship with salinity during the high river discharge period. During premonsoon period, a sharp decrease of silicate with distance in the middle regions between salinity range of 4 to 22×10^3 in the estuary was observed. River discharge was found to modulate both estuarine residence time and the DSi supply. The substantial removal of DSi (approximately 50 %) during premonsoon was attributed to enhanced biological utilization, caused by the development of null zones in the middle areas of the estuary.

Introduction

Distribution of dissolved silica (DSi) in estuaries differs from other major micronutrients, since the main DSi source is river discharge coupled with an insignificant contribution from recycling by dissolution of siliceous diatoms (Patterson *et al.*, 1975; Anderson, 1986). Silica utilization is normally by phytoplankton in synthetic processes and by inorganic removal onto suspended matter (Liss and Spencer, 1970). Although a few published informations are available on the distribution of silicate in this area (Sankaranarayanan and Qasim, 1969; Sankaranarayanan, Joseph, Jayalakshmi and Balachandran, 1984; Sankaranarayanan, Varma, Balachandran, Pylee and Joseph, 1986) and other estuaries of India (Borole, Krishnaswamy and Somayajulu, 1977; Sarin, 1985; Burton, Liss and Venugopalan, 1970b) an exhaustive study on the silicate behaviour during the estuarine mixing is lacking. An attempt has been made here to study the behaviour of DSi in this estuarine system during different seasons of the year.

Materials and Methods

Water chemistry observations were made within 48 hrs at as many as 20 stations in the mid-channel of the estuary between river mouth and the freshwater boundaries of northern Periyar and southern Muvattupuzha rivers during the flood tide. Monthly hydrographic studies were made for two years from July 1989 to May 1991. Water samples collected from surface (0-0.5m) and 0.5m above the bottom were filtered through whatmann filter paper no.1. Salinity was estimated using inductive laboratory model salinometer (Tsurumi Seiki Model 3 G DIGI AUTO, accuracy 0.01×10^{-3}). Silicate was measured by silicomolybdate method as given in Grasshoff (1983)(accuracy + $4 \mu\text{g at/l}$).

Results and Discussion

Temporal and spatial variations

In order to understand the temporal and spatial variations

in DSi, the study period is divided into 3 seasons *viz.*, Premonsoon (February - May), SW monsoon (June- September) and postmonsoon (October- January). The salinity intrusion in the northern and southern limbs of the estuary responds closely to the variations in river discharge. The intrusion of salt water into the estuary was deep, the distance being 25 km in Muvattupuzha and 21 km in Periyar from the barmouth (1989-90). For monsoon months the saline intrusion is limited to 10 km. During the premonsoon, the estuary becomes dominated by neritic waters leading to near vertical homogeneity. During monsoon season, the entire estuarine water is flushed out and replaced by freshwater. There is a short fall in river discharge between September and October when again the northeast monsoon brings in moderate precipitation from late October to January resulting in considerable river discharge, though much less than that in the SW monsoon period. During this period, the estuary behaves as partially mixed one until December. The extent of saline intrusion was more in the southern part as compared to the northern part throughout the year. This is probably due to a higher river discharge through river Periyar compared to Muvattupuzha. Levels of silicate in the present study varied from 4.43 to $139.4 \mu\text{g at/l}$ at the surface and 6.14 to $133.4 \mu\text{g at/l}$ at the bottom. In Muvattupuzha, the average silicate concentration varied between 4.03 and $138.15 \mu\text{g at/l}$, while in Periyar it ranged between 5.20 to $140.1 \mu\text{g at/l}$. Monsoon and postmonsoon peaks in silicate content for both rivers indicated that the silicate source to this estuary is by river run off, which is in clear agreement with earlier works (Sankaranarayanan and Qasim, 1969; Sai Sastry, 1990; Gouda and Panigraphy, 1992).

Plots of chemical constituents vs. salinity have been used to demonstrate uptake, addition or conservation of a given constituent within an estuary (Liss, 1976). These concepts were extended by Patterson, Conomos *et al.*, 1975). DSi - salinity relations of the Cochin backwaters during monsoon, postmonsoon and premonsoon seasons are given in Figs. 1 a,b

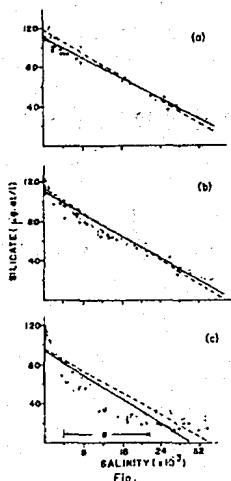


Fig. 1. Dissolved Silicate - Salinity relationship during different seasons for two years in the Cochin backwater system as a whole. (a) DSi vs. S% during monsoon 1989 and 1990. (b) DSi vs. S% during postmonsoon 89 and 90. (c) DSi vs. S% during premonsoon 1990 and 91.

and c respectively. For this the individual values were averaged out for each season and plotted. The DSi-salinity (S) relationship during monsoon 1989 and 90 is linear given (Fig. 1a) by

$$\text{DSi} = 119.16 - 2.98 S \text{ Correlation coefficient } r = -0.97 \text{ and}$$

$$\text{DSi} = 109.81 - 2.65 S r = -0.98$$

linear relation between DSi and salinity is also observed during postmonsoon season

$$\text{DSi} = 110.33 - 2.91 S r = -0.98 \text{ and}$$

$$\text{DSi} = 107.51 - 2.76 S r = -0.98$$

for 1989 and 1990 respectively (Fig. 1b). It is thus clear that dissolved silicate bears a linear relationship with salinity during monsoon and postmonsoon seasons. A linear distribution of this kind indicates that mixing rates between river and seawater dominate over non-conservative processes (Patterson *et al.*, 1975). During premonsoon season, however, the DSi-Salinity relationship is not linear (Fig. 1c), but forms a curvilinear shape. The relation is best explained by the exponential equations, $\text{DSi} = 95.32 * e^{-0.05181 S}$ and $\text{DSi} = 99.82 * e^{-0.06868 S}$.

For years 1990 and 91 (Figs. 2 a & b). Premonsoon DSi-salinity relationship thus implies that the estuary behaves as a sink for river-supplied dissolved silicate. Let us examine whether such removal of DSi is by inorganic or organic process. Experimental studies by Wollast and Peter, 1976; on silicate changes at light and dark condition and Borole *et al.*, 1977 at different salinity ranges have ruled out the possibility of silicate removal onto suspended matter. In the present study, since the amount of DSi removed is far too high (approximately 50%), inorganic removal alone cannot account for the anomaly. According to Li Faxi (1979), the degree of DSi removal may depend on hydrographic and biological conditions of the particular estuary. We believe that the principal factors

influencing the loss of DSi from this estuary are the development of watermass with high residence time during premonsoon which favours enhanced primary productivity. The peculiar topography of this estuary with the two perennial rivers entering the estuary from opposite directions, a system of canals connecting the two and the seaward opening at right angle to their direction of flow makes the hydrodynamics of estuarine circulation complex. As the river discharge decreases, the estuary is gradually dominated by tidal influence which forces the neritic water into the upper reaches of the estuary, against a weak river discharge. In such conditions, there develops a non tidal mean flow representing a body of water column with a high residence time compared to other seasons, called "null zone" (Patterson *et al.*, 1975). The sections adjacent to this zone (both upstream and downstream) will be having a residual flow towards the zone, thus enriching the zone with nutrients. Flushing time of the estuary in general increases resulting in a net accumulation of any material discharged into the estuary towards the null zone. Available information also supports the view that primary productivity in this estuary remain high during premonsoon season and with occasional bloom of phytoplankton during the rest of the period (Joy, Balakrishnan and Joseph, 1990; Nair *et al.*, 1975; Qasim, 1979; Gopinathan, 1984; Nair *et al.*, 1988; Joseph and Pillai, 1975). The standing stock of Chlorophyll 'a' pigments (54.5 mg.m^{-3}) and biomass recorded are highest during this season (Joy *et al.*, 1990) and are mainly constituted by diatoms and dinoflagellates (Joseph and Pillai, 1975), which are the main consumers of silicon in the water.

In the light of above conditions, we can explain the salient features pointed out earlier. During monsoon and postmonsoon seasons, moderately high rate of supply of DSi through river discharge compensates the removal, if any, from the estuary explaining the near-linear relationship between DSi and salinity (Fig 1a and 1b). During premonsoon period, the river discharge becomes low, decreasing the rate of supply of DSi. The productivity can be increased due to enrichment of N and P fractions into the null zone. But the primary nutrients necessary for primary productivity are N, P and Si, of which the last is not in surplus. This leads to utilization of DSi from the river input, at a greater rate than its addition through river discharge. The net result is, an observed removal of DSi from the estuary between salinity range $4 - 22 \times 10^{-3}$ marked by the zone 'B' in Fig. 1c. Within the limitations of our field surveys carried out, we find that this 25 km stretch of Cochin backwaters with salinity range of 4 to 22×10^{-3} behaves as a biologically active zone, during the premonsoon period of 1990. Another noticeable feature is that the null zone was found to extend more towards the southern side than towards the north. This can be explained by difference in the river discharge through these two rivers. The southern portion of the estuary is also characterised by seaward increase of cross channel area.

The fractional loss of DSi within an estuary (G)

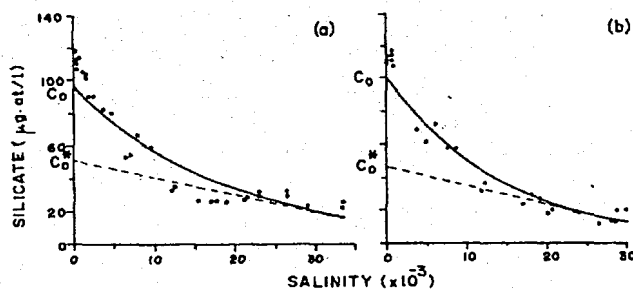


Fig 2. Fractional loss of DSi in Cochin backwaters during premonsoon seasons of (a) 1990 and (b) 1991. C_0 = Fresh water end concentration of DSi and C_0^* = Extrapolated value of lower estuary DSi concentration to zero salinity

approximated by the method of Hydes and Liss (1977) and extended by Officer (1979) for this estuary is given as $G = (C_0 - C_0^*) / C_0$, where C_0^* is the extrapolated silicate value corresponding to zero salinity of the linear lower estuary silicate distribution and C_0 as the freshwater end point DSi concentration. This fractional loss for the Cochin backwaters $G = 45.4\%$ and 53.1% during premonsoon seasons of 1990 and 1991 respectively (Fig.2) are comparable with the values reported by Callaway and Specht, 1982, but high compared to the values reported by Liss (1976).

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