Seasonal distribution and behaviour of silicate in the Rushikulya estuary, east coast of India

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Reactive silicate and salinity values in surface and bottom waters of Rushikulya estuary showed well marked seasonal fluctuations. The annual cycle of silicate exhibited unimodal oscillation with peaks and falls occurring during monsoon and premonsoon seasons respectively. The concentration of silicate (μg-at.l⁻¹) in surface water ranged from 4.12-191.86, while in bottom water it varied between 4.37 and 195.27. Significant inverse relationship between salinity and silicate indicated that freshwater influx is the principal source of silicate for this environment.

Reactive silicate, which forms a major dissolved constituent in river water, undergoes measurable changes during estuarine mixing, being influenced by some chemicals and biological processes of the ambient water, besides mere physical mixing. Although much work has been done on the seasonal distribution of silicate in some estuaries of India¹⁻⁶, similar studies are meagre in the estuaries of Orissa coast⁷. The present paper deals with the seasonal distribution and behaviour of silicate in the Rushikulya estuary along Orissa coast.

Materials and Methods
Surface and bottom water samples were collected at fortnightly intervals during Jan. 1988-Dec. 1989 from different sites (Fig. 1) covering the stretch from the mouth to freshwater zone of Rushikulya estuary. All collections were made during ebb-flood period. Samples were filtered through glass fiber filter papers (GF/C of 0.45 μm) before analysis. Salinity was determined as per Knudson’s titrimetric method and silicate by spectrophotometric method⁸. Values of salinity and silicate were averaged month wise (Jan.-Dec.) and seasonwise viz. premonsoon (Feb.-June), monsoon (July-Sept.) and postmonsoon (Nov.-Jan.) to illustrate their distribution pattern. Simple correlation and regression analyses were made taking all the average data of each year and also at salinity subranges of 0-10, 10-20, 20-30, and > 30 × 10⁻³ to establish their interrelationships.

Results and Discussion
Seasonal distribution—Salinity and silicate concentration (Fig. 2) showed well marked seasonal variations, which seem to be mainly influenced by freshwater influx at one end and intrusion of seawater on the other. The annual cycle of salinity (Fig. 2) exhibited unimodal oscillation every year. Peaks and falls were observed corresponding to premonsoon (April-May) and monsoon seasons respectively. Salinity values varied between 0.5 and 34.7 × 10⁻³ in 1988 and 0.038 and 35.7 × 10⁻³ in 1989. Such a wide range of variation coupled with unimodal annual cycle of salinity were commonly reported from several Indian estuaries³⁻⁴,⁷,⁹⁻¹⁴. Salinity conditions of different seasons discerned different pictures. Lowest salinities occurred during peak monsoon months, when the intensity of freshwater influx was highest. Both horizontal and vertical gradient of salinity at this time were absent since the estuary, as a whole, was flooded with freshwater. After the cessation of monsoon floods, seawater intrusion could take place, and consequently, the salinity
began increasing. This occurred throughout the postmonsoon season resulting in gradual increase of salinity from October till February/March. Horizontal gradient with a decreasing trend towards upstream and vertical gradients were observed. Maximum salinities were encountered from March-May, as the freshwater inundation was almost negligible. The entire estuary during this period was dominated by neritic waters. Similar pattern of salinity distribution with extreme conditions corresponding with monsoon and premonsoon seasons and a transitory recovery postmonsoon season have been reported earlier in Vellar\textsuperscript{11,12}, Goutami-Godavari\textsuperscript{10,14} and Zuari and Mandovi estuaries\textsuperscript{3,9}. Levels of reactive silicate with present study varied from 4.12-191.96 µg-at.\textsuperscript{1} at surface and 4.37-195.27 µg-at.\textsuperscript{1} at bottom. Like salinity silicate also exhibited unimodal oscillation during both the years. Both peaks and falls were encountered corresponding to monsoon and premonsoon seasons. A constant seaward decrease was noticed in all 3 seasons, but was least pronounced when the estuary as a whole was flooded with freshwater. The vertical gradient, in general, was not well recognisable. Interseason comparison revealed that
during monsoon, concentration was higher than in other 2 seasons. Very low silicate concentrations were noticed during April-May which is noteworthy.

Gradual seaward decrease coupled with higher monsoonal concentrations indicate that intrusion of silicate into the estuary mainly takes place through surface runoff, which is in agreement with earlier observations made in Cochin backwater\textsuperscript{1,2}, Mandovi and Zuari estuaries\textsuperscript{3}, Vellar estuary\textsuperscript{4-6}, Goutami-Godavari estuary\textsuperscript{10} and Mahanadi estuary\textsuperscript{7}. Lowest silicate concentrations concomitant with the occurrence of diatom bloom during April-May suggest that biological utilisation acts as an important factor associated with removal of silicate from the medium. Similar instances of silicate depletion concurrent with occurrence of diatom bloom have also been reported from Vellar estuary\textsuperscript{13,16}, Cochin backwater\textsuperscript{4}, nearshore waters of Gopalpur sea\textsuperscript{17}, off Waltair\textsuperscript{18} and in the lower reaches of the present study area\textsuperscript{19}.

Although the pattern of seasonal cycle seems to be similar to many other estuaries, considerable differences are seen with respect to the range of concentrations and behaviour. The levels of silicate

<table>
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<tr>
<th>Locality/reference</th>
<th>Range of concentration</th>
<th>Mode of annual cycle/behaviour</th>
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<tr>
<td>Estuaries of Goa</td>
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<tr>
<td>(i) Mandovi\textsuperscript{3}</td>
<td>10-160 μg-at.l\textsuperscript{-1}</td>
<td>Unimodal oscillation, maximum conc. in monsoon season; conservative behaviour</td>
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<td>(ii) Mandovi estuary\textsuperscript{3}</td>
<td>71.5-138.5 μ mol \textsuperscript{-1}</td>
<td>Non conservative behaviour*</td>
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<td>(iii) Zuari\textsuperscript{3}</td>
<td>10-190 μg-at.l\textsuperscript{-1}</td>
<td>Unimodal oscillation, maximum conc. in monsoon season; conservative behaviour</td>
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<tr>
<td>Cochin backwaters\textsuperscript{5}</td>
<td>5-60 μg-at.l\textsuperscript{-1}</td>
<td>Unimodal oscillation, maximal conc. in monsoon season; non-conservative behaviour</td>
</tr>
<tr>
<td>Cochin backwaters\textsuperscript{2} and Pariyar river</td>
<td>0.03-4.75 mg l\textsuperscript{-1}</td>
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<td>Cochin backwater\textsuperscript{4}</td>
<td>28.0-185.3 μg-at.l\textsuperscript{-1}</td>
<td>Unimodal oscillation, maximal conc. in monsoon season; conservative behaviour</td>
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<td>Korapuzha estuary\textsuperscript{13}</td>
<td>20-260 μg-at.l\textsuperscript{-1}</td>
<td>Unimodal oscillation, maximal conc. in monsoon season</td>
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<td>Vellar estuary\textsuperscript{5}</td>
<td>16.60-129.69 μg-at.l\textsuperscript{-1}</td>
<td>Unimodal oscillation, maximal conc. in monsoon season; conservative behaviour</td>
</tr>
<tr>
<td>Vellary estuary\textsuperscript{6}</td>
<td>6.126 × 10\textsuperscript{3} μg-at.l\textsuperscript{-1}</td>
<td>Non conservative behaviour**</td>
</tr>
<tr>
<td>Mahanadi estuary\textsuperscript{7}</td>
<td>24-207 μ mol dm\textsuperscript{-3}</td>
<td>Maximal concs. in river end in monsoon months</td>
</tr>
<tr>
<td>Present study (Rushikulya estuary)</td>
<td>5.051-193.569 μg-at.l\textsuperscript{-1}</td>
<td>Unimodal oscillation, maximal conc. in monsoon season; nonconservative behaviour</td>
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* Behaviour studied during Feb.-May 1981
** Behaviour studied during postmonsoon season (1968-1969)
in the present study are fairly similar to those of Zuari estuary\(^3\). About 19 fold increase was evident in the Zuari estuary\(^3\) as against 7 fold in Cochin backwaters\(^2\), 16 fold in Mandovi estuary\(^3\), 8 fold in Vellar estuary\(^5\), 13 fold in Korapuzha estuary\(^13\), 9 fold in Mahandi estuary\(^7\). The behaviour of silicate was non conservative as commonly encountered in many other estuaries (Table 1).

The simple correlation and regression analyses between salinity and silicate for each year (Fig. 3) and also at salinity subranges 0-10, 10-20, 20-30 and > 30 x 10\(^{-3}\) (Fig. 4) showed significant inverse relations \((P<0.001)\). However, many scattered points were noticed in each case. This indicates that the behaviour of silicate is not only governed by simple dilution process, but also by some other phenomena. Addition of Si by dissolution of river borne particulates\(^20\) and removal of soluble silicate by adsorption onto suspended matters, co-precipitation with humic compounds and iron\(^{21}\) and diatom uptake\(^2,15,10\) significantly influence the distribution and behaviour of silicate in estuaries. Scrutiny of results (Fig. 4) revealed that considerable deviations from the linearity occurred at low salinities \((0-10 \times 10^{-3})\) than at higher salinities, viz. 10-20, 20-30 and > 30 x 10\(^{-3}\). This suggests that processes like adsorption onto the suspended sediments, co-precipitations and chemical reactions with clay minerals considerably affect the distribution of silicate since the estuary was filled with silicate rich and silt borne riverine water and plankton production was very less.

Acknowledgement

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References

5 Kannan K & Krishnamurthy K, in Marine plants-their biology, chemistry and utilization, edited by V Krishnamurthy