

Atypical Behaviour of Dissolved Silicate in the Cochin Backwater & Periyar River

V N SANKARANARAYANAN, T JOSEPH, K V JAYALAKSHMY & K K BALACHANDRAN
 National Institute of Oceanography, Regional Centre, Cochin 682018

Received 10 October 1983; revised received 7 March 1984

Dissolved silicate was determined for 1 y (1982-83) covering a wide range of salinity from the estuarine mouth to the fresh water region. Silicate concentration ranged between 0.03 and 4.75 mg l⁻¹. Silicate-salinity relationship was linear and inverse in the salinity ranges 0.5 × 10⁻³ and 5-35 × 10⁻³. Since variability in the distribution of silicate explained by the significant linear regression model was small in the subranges of salinity 5-20 and 20-30 × 10⁻³, a curvilinear regression model was fitted and it gave a good fit at 5% level (*P* > 0.05). The expected removal of silicate at salinity range 0.5 and 5-35 × 10⁻³ given by linear relationship was 28.8 and 51.1% respectively. In 5-20 and 20-30 × 10⁻³ at 5 and 20 × 10⁻³ salinity the expected removal as given by curvilinear relationship was 31.94 and 6.068% respectively.

Distribution of dissolved silicate in the sea has been studied extensively. Several workers have studied the behaviour of silicate during the estuarine mixing¹⁻⁴. Very little information is available¹ on the silicate distribution in the Indian estuaries, though it is of interest to note its behaviour during the estuarine mixing processes.

This paper presents the behaviour of silicate in relation to salinity in the Cochin backwater and in Periyar river.

Materials and Methods

Water samples were collected from Cochin backwater and Periyar River at monthly intervals during 1982-83 from marine zone to fresh water region covering a wide range of salinity (Fig.1). The station depths varied between 2 and 7 m. Samples were collected from the surface and bottom and stored in polyethylene bottles and analysed immediately. Dissolved silicate by spectrophotometric method⁵, and salinity by titration method⁶ were estimated. A linear regression model was fitted and its significance tested using ANOVA technique⁷, based on the significance of linear correlation.

Salinity ranges in 0.35 × 10⁻³ were combined and grouped into 2 as 5-20 × 10⁻³ and 20-35 × 10⁻³. For the 2 groups separately and for the whole the same linear regression model was fitted and its significance tested as above. Since linear relationship was not significant for the subranges a curvilinear model was fitted for 2 groups. The fitted equation⁸ was

$$Y = Y_i + \frac{X^2}{a_0 + a_1 X + a_2 X^2}$$

where *Y_i* = silicate concentration at the *i*th salinity level; *i* = 5,20; *Y* = silicate; *X* = salinity; *a*₀, *a*₁, *a*₂ are

curvilinear regression coefficients. This model was fitted for the average of silicate and salinity concentration in each interval of 5 units in each range. The fitted model was found to be good fit using χ^2 statistic at 5% level. For linear and curvilinear relationships, the expected removal of silicate at 0 salinity in different ranges was computed.

Results and Discussion

There is a vast change in the salinity conditions at all stations except at the estuarine mouth where the salinity changes are less during the year (Table 1).

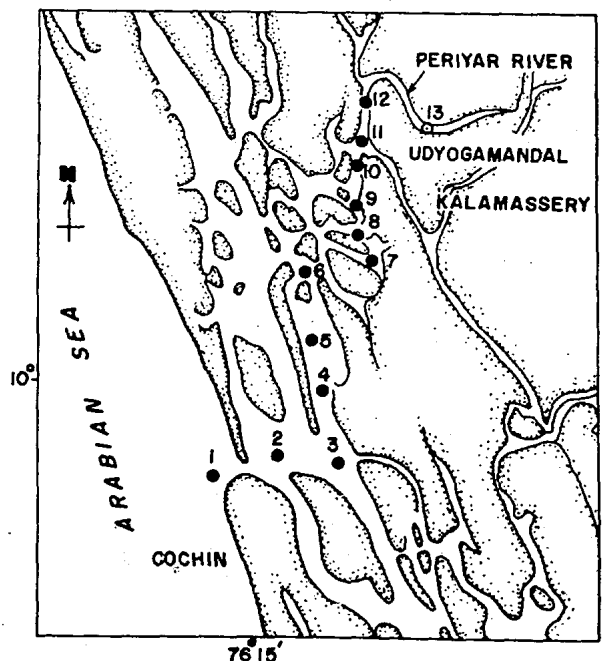


Fig. 1—Cochin backwaters and Periyar river showing station positions

Table 1—Salinity ($\times 10^{-3}$) at Different Stations during Different Months

St		1982						1983					
		June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
1	S	0.45	1.45	27.78	29.27	18.25	24.12	32.69	32.52	33.08	33.15	33.87	28.45
	B	16.26	29.18	25.80	33.07	33.33	33.15	33.33	33.24	32.16	34.32	34.14	30.62
2	S	0.54	1.26	0.72	25.47	11.18	26.10	29.81	29.18	29.10	29.54	30.89	27.28
	B	17.61	8.04	3.64	9.39	32.88	33.06	32.79	33.35	29.63	32.88	32.43	29.18
3	S	0.36	0.63	0	8.58	9.12	17.43	24.12	29.18	29.72	31.34	31.34	26.92
	B	0.18	0.54	0	10.12	14.27	30.53	33.15	31.25	30.17	31.16	31.79	27.01
4	S	0.27	0.05	0	9.30	8.94	13.73	24.03	28.00	30.35	30.71	32.88	26.92
	B	0.18	0.09	0	—	28.01	29.36	30.62	28.45	30.53	30.80	33.06	26.83
5	S	0.18	0.05	0	—	9.76	11.15	22.04	27.46	29.63	30.17	31.98	24.84
	B	0.18	0.05	—	—	16.44	13.10	26.47	27.64	29.63	30.26	32.16	24.84
6	S	0	0.09	0	7.86	6.87	9.67	17.98	26.20	26.83	29.99	31.34	19.78
	B	0	0.09	0	9.21	15.54	10.48	21.68	26.28	26.83	29.90	31.52	19.78
7	S	0	0.05	0	2.44	1.63	6.02	13.19	24.75	25.47	29.36	30.53	17.16
	B	0	0.05	0	5.51	5.60	7.00	17.79	24.75	25.56	29.26	30.89	17.16
8	S	0	0.05	0	0.14	0.38	2.35	10.39	22.04	22.76	27.10	28.54	8.76
	B	0	0.05	0	2.35	0.38	7.72	18.88	22.76	23.12	27.73	29.08	17.16
9	S	0	0.05	0	0.09	0.42	0.42	6.05	20.41	21.23	24.66	27.46	6.50
	B	0	0.05	0	0.05	0.43	3.88	15.27	20.41	22.22	26.65	28.81	17.25
10	S	0	0.05	0	0.05	0.29	1.72	6.05	10.80	20.59	25.20	27.64	6.77
	B	0	0.05	0	0.05	0.33	4.07	12.01	11.25	21.77	27.10	28.63	25.92
11	S	0	0.05	0	0.05	0.27	0.81	1.00	16.62	20.96	19.96	19.15	6.77
	B	0	0.05	0	0.05	0.29	0.72	1.63	17.61	21.77	26.65	25.92	20.32
12	S	0	0.05	0	0.05	0.22	0.90	4.21	12.65	20.14	20.96	23.48	7.23
	B	0	0.05	0	0.09	0.25	0.81	0.69	12.92	21.14	26.47	29.27	18.16
13	S	0	0.05	0	0.05	0.20	0.09	0.78	2.44	15.81	19.20	17.56	7.95
	B	0	0.05	0	0.05	0.15	0.18	0.84	5.33	20.68	23.10	22.80	12.28

S=surface, B=bottom

There is a general increase in the silicate concentration from the mouth of the estuary to upstream (Table 2). Average silicate concentration (mg l^{-1}) varies from 0.37 to 5.96, 0.21 to 4.73 and 0.03 to 2.66 respectively in monsoon, postmonsoon and premonsoon seasons from the barmouth to upstream. Highest silicate concentration is observed at the surface. There is a general decrease in the silicate content from Oct. to May. In the upper reaches of Periyar where the salinity influence is less, the concentration is comparatively uniform throughout the year. All samples have been collected at a similar stage of tidal cycle. Nevertheless the major changes in the silicate concentration observed are due to differences in dilution and the concentration is maximum when the fresh water flow is maximum. The silicate distribution appears to be largely governed by the river water discharge. Maximum concentration of silicate (1.7 to 6.7 mg l^{-1}) occurs during SW monsoon when the river water discharge is maximum. But during the premonsoon season when the river discharge is minimum the variation and the concentration of silicate are minimum (0.03 - 2.66 mg l^{-1}).

Variation in the concentration of salinity decreases steadily from 195 to 3%. Whereas in silicate, it reaches

to a maximum of 443% in the salinity range 10 - 25×10^{-3} and falls to a minimum of 47% in the lower (0 - 5×10^{-3}) and higher (30 - 35×10^{-3}) ranges. Correlation coefficient is negative in all cases except in the salinity range 10 - 15×10^{-3} and it is significant only in 0 - 5×10^{-3} . It is further suggested that dilution has significant inverse effect at 5% level only in the salinity range 0 - 5×10^{-3} .

The fitted linear regression equation for different salinity ranges ($\times 10^{-3}$) are:

$$\begin{aligned}
 Y &= -0.4445 X + 3.3808 \text{ for } 0-5 \\
 Y &= -0.2566 X + 4.0231 \text{ for } 5-10 \\
 Y &= 0.1222 X - 0.0049 \text{ for } 10-15 \\
 Y &= -0.2099 X + 5.1256 \text{ for } 15-20 \\
 Y &= -0.0136 X + 0.8482 \text{ for } 20-25 \\
 Y &= -0.0055 X + 1.0587 \text{ for } 25-30 \\
 Y &= -0.1029 X + 4.0212 \text{ for } 30-35
 \end{aligned}$$

where Y is silicate and X is salinity.

The fitted linear regression model was significant only in salinity range 0 - 5×10^{-3} (F ratio 30.25; $P < 0.05$) and variability explained was only 7.382%. Since linear regression model was not significant for the remaining ranges, they were all combined and

redivided into 2 ranges $5-20 \times 10^{-3}$ and $20-35 \times 10^{-3}$. The correlation coefficient was calculated and the same model was again fitted for the 2 separately and together.

The fitted equations for the 2 salinity ($\times 10^{-3}$) ranges and the combined one are:

$$Y = -0.0508 X + 2.3203 \text{ for } 5-20$$

$$Y = 0.0147 X + 0.3594 \text{ for } 20-35$$

$$Y = -0.0556 X + 2.3234 \text{ for } 5-35$$

Since linear model was significant only for the salinity range $5-35 \times 10^{-3}$ (F ratio = 59.1776; $P < 0.05$) the fitted linear equation in this range was extended to salinity 0 and the expected removal was estimated as 51.1%. The variability explained was only 19.57% (Table 3). Therefore the unexplained variability may be due to different types of relationships between silicate

and salinity; in the salinity sub-ranges $5-20 \times 10^{-3}$ and $20-35 \times 10^{-3}$. Since linear relationship did not hold good for these 2 ranges, a curvilinear model was fitted and it was:

for sal. $5-20 \times 10^{-3}$

$$Y = 1.047 + \frac{X^2}{-211.4349 + 13.8129 X + 2.7041 X^2}$$

for sal. $20-35 \times 10^{-3}$

$$Y = 0.6163 +$$

$$\frac{X^2}{-46048.107 + 1748.5109 X + 0.9746 X^2}$$

The model was fitted using the average values of silicate and salinity in each interval of 5 units in each range. The fitted model gave a good fit for both ranges

Table 2—Silicate (mg.l^{-1}) Distribution at Different Stations

St	1982							1983					
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	
1	S	4.46	3.86	3.64	0.61	1.47	0.97	0.24	0.53	0.76	0.37	0.61	0.26
	B	2.49	0.95	3.55	0.37	0.68	0.39	0.21	0.44	0.69	0.61	0.70	0.31
2	S	4.71	3.87	5.96	0.75	1.31	0.69	0.38	0.50	0.66	0.41	0.78	0.25
	B	3.14	3.25	3.26	1.67	0.42	0.43	0.25	0.60	0.77	0.36	0.79	0.30
3	S	3.85	4.57	3.73	2.79	1.61	1.09	0.72	0.63	0.81	0.45	0.84	0.27
	B	2.70	4.99	3.73	1.91	1.45	0.60	0.43	0.43	0.74	0.42	0.80	0.27
4	S	4.90	6.07	1.94	1.77	1.66	0.64	0.94	0.76	0.86	0.62	0.91	0.41
	B	2.93	6.53	3.97	2.00	2.14	2.01	0.43	0.69	0.85	0.67	0.89	0.48
5	S	2.59	4.13	3.97	—	2.31	1.55	0.99	0.70	0.91	0.89	1.18	0.89
	B	4.12	4.24	—	—	1.89	2.06	0.78	0.67	0.87	0.82	1.42	1.06
6	S	4.08	4.03	3.40	2.14	2.87	2.15	1.03	0.77	0.71	0.88	1.22	1.15
	B	3.90	4.38	3.78	2.42	2.08	2.76	1.08	0.49	0.61	0.74	1.17	0.99
7	S	4.70	3.75	3.59	4.05	3.85	2.72	1.42	0.61	0.65	0.74	1.37	1.34
	B	2.74	2.83	3.69	3.16	3.10	3.61	1.43	0.16	0.57	0.65	1.34	1.22
8	S	3.61	4.26	3.59	4.33	4.05	3.04	1.81	0.54	0.11	0.31	1.30	2.23
	B	3.96	2.65	3.59	4.05	3.77	4.73	1.19	0.66	0.34	0.46	1.49	1.69
9	S	4.94	6.70	3.68	4.31	4.05	3.70	2.83	0.30	0.03	0.55	1.34	2.55
	B	4.09	3.76	3.69	4.33	4.23	3.79	1.73	0.04	0.27	0.66	1.70	1.79
10	S	4.71	3.44	3.50	4.33	3.86	3.93	2.16	0.19	0.10	0.39	1.59	2.67
	B	3.72	3.75	3.40	4.23	4.05	4.08	1.46	0.89	0.24	0.78	1.95	1.82
11	S	2.10	3.30	3.69	4.70	3.85	4.12	3.47	0.79	0.22	0.12	0.22	2.66
	B	2.08	3.78	3.78	4.98	3.96	4.64	3.47	1.82	0.38	0.72	0.84	1.80
12	S	2.51	3.26	3.69	4.14	3.96	4.45	3.94	1.41	0.12	0.31	0.49	2.10
	B	2.62	2.47	2.84	4.05	4.10	3.42	3.75	0.50	0.28	1.20	1.28	1.34
13	S	3.00	3.61	3.40	3.95	3.96	1.55	3.84	0.48	0.10	0.33	0.31	6.80
	B	2.69	3.62	3.31	4.05	4.12	3.51	4.22	0.41	0.54	0.64	0.76	3.22

S=surface, B=bottom

Table 3—Removal of Silicate for All Salinity Ranges and Variability Explained by Linear Regression Model

	Sal. range ($\times 10^{-3}$)			
	0-5	5-20	20-35	5-35
Percent silicate removed at (sal. $\times 10^{-3}$)	28.83 at (0)	31.94 at (5)	6.068 at (20)	51.09 at (0)
Explained variability (%)	7.38	—	—	19.57

by χ^2 test at 5% level ($P > 0.05$). Therefore the reduction in the variability explained by the linear regression model in the salinity range $5-35 \times 10^{-3}$ can be attributed to different types of curvilinear relationships existing between silicate and salinity in the salinity ranges $5-20 \times 10^{-3}$ and $20-35 \times 10^{-3}$. Using these 2 equations the expected removal of silicate at 5 and 20×10^{-3} salinity is 31.94% and 6.068% respectively (Table 3). Burton *et al.*⁹ observed only values 2% less than the measured concentration for the test estuary and thereby ruling out the possibility of any silicate removal by precipitation when the freshwater mixes with seawater. Substantial removal of dissolved silicate from river water entering the Mississippi Delta has been suggested by Bien *et al.*². Burton¹ has reported 10% removal of dissolved silicon in the upper estuary of the Vellar river. The variation in the concentration observed over the year in the estuarine mouth have been associated with the biological factors such as high phytoplankton production occurring in these waters¹⁰. In other regions of the estuary the biological effect on the distribution of silicate seems to be minor.

Eventhough linear model was found to be significant in $0-5 \times 10^{-3}$ salinity the explained variability is very low. This may be due to precipitation. Similarly, in the salinity range $5-35 \times 10^{-3}$ the explained variability is

little more, but much less than 50%. Since curvilinear relationship gave a good fit in the subsalinity ranges $5-20 \times 10^{-3}$ and $20-35 \times 10^{-3}$, a part of the unexplained variability may be due to removal but at a lower rate.

Acknowledgement

The authors express their gratitude to Dr V V R Varadachari, Director, for his interest, to late C V G Reddy for going through the paper and to Dr M Krishnan Kutty, Scientist-in-Charge, RC of NIO for the help.

References

- 1 Burton J D, *J Cons Perm Int Explor Mer*, 33 (1970) 141.
- 2 Bien G S, Contois D E & Thomas W H, *Geochim Cosmochim Acta*, 14 (1958) 35.
- 3 Meeda H & Takesue K, *Rec Oceanogr Wks Japan*, 6 (1961) 112.
- 4 Stefansson U & Richards F A, *Limnol Oceanogr*, 8 (1963) 394.
- 5 Mullin J B & Riley J P, *Anal Chim Acta*, 12 (1953) 162.
- 6 Barnes H, *Apparatus and methods of oceanography, Part I: Chemical* (Oxford University Press, London) 1960.
- 7 Snedecor G W & Cochran G W, *Statistical methods* (Oxford and IBH Publishing Co, Calcutta) 1967.
- 8 Kamat S B & Sankaranarayanan V N, *Indian J Mar Sci*, 4 (1975) 399.
- 9 Burton J D, Liss P S & Venugopalan V K, *Cons Perm Int Explor Mer*, 33 (1970) 134.
- 10 Qasim S Z, Wellershhaus S, Bhattathiri P M A & Abidi S A H, *Proc Indian Acad Sci*, 69 (1969) 51.