ON THE VERTICAL DISTRIBUTION OF CHEMICAL CONSTITUENTS IN THE SHELF WATERS OFF WALTAIR

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INTRODUCTION

THE Zoology Department of Andhra University has taken up the study of the chemistry and biology of the Western Bay of Bengal, with special reference to its hydrography. Several studies have already been completed, among which are those of Ganapati *et al.* (1954, 1955), who have related the surface currents to salinity, temperature and planktonic conditions. The environmental factors effecting vertical circulation, namely, upwelling and sinking, have been discussed by La Fond (1954 *a*, *b*). The present investigation is directed towards the study of the vertical distribution of salinity, phosphate, silicate and oxygen and their relation to the currents and biology of the area.

Data.—On the Andhra University Oceanographic cruises, vertical series of water samples were taken at most of the 700 odd stations occupied. These samples were analysed in the laboratory for the various chemical constituents. For example, the salinities were determined by the classical Knudsen's method; inorganic phosphates by the method of Deniges as modified by Robinson and Thompson (1948); silicates by the Dienert and Wandenbulcke method as modified by Robinson and Thompson (1948); and the dissolved oxygen content by the Winkler method. Seven representative examples of the vertical series detailing the chemical properties are given in Table I. These were chosen to illustrate both the vertical chemical structure of the water and the changes which occurred from October 1955 to May 1956. All stations occupied were on the continental shelf just off Waltair as indicated by the latitude and longitude.

It can be seen from the tabulated salinity that the surface values run from 15·59‰ in October to 33·49‰ in May, whereas the near bottom salinity increases from 31·13‰ to 35·16‰. The striking difference between surface and bottom salinity is shown in Fig. 1.

The phosphates were observed to be rather constant at the surface throughout this season, ranging from 0·48 to 0·62 μg. atoms. The subsur-

TABLE I

Chemical Data from Seven Oceanographic Stations off Waltair

Station number	Date	Latitude (° N.)	Longitude (° E.)	Water Depth (metres)	Salinity (‰)	Phosphate (μg. at /L.)	Silicate μg. at /L.)	Dissolved Oxygen (ml./L.)
479 X	28–10–1955	17° 14·9′ N.	83° 19·8′	0	15·59	·69	4·9	3·83
				8	23·86	·72	7·8	2·82
				16	31·13	·84	8·1	2·79
487	10–11–1955	17° 26·0′	83° 24·5′	0	23·19	·61	6·2	3·11
				8	28·40	·79	8·7	3·09
				20	29·88	·84	10·0	2·89
				41	31·36	·87	11·2	2·83
				61	32·66	·99	12·2	2·83
524 B	13–12–1955	17° 41·5′	83° 30·0′	0	28·46	·61	5·3	3·63
				9	28·96	·87	5·6	3·43
				18	31·17	·94	6·5	3·42
				26	31·82	1·02	6·8	2·92
				44	32·47	1·30	8·2	2·43
591	17—2–1956	17° 33·0′	83° 26·0′	0	32·20	·48	7·5	3·93
				29	32·63	·53	8·2	3·79
				49	33·24	·59	8·7	3·03
				59	33·93	·76	9·3	2·48
				64	33·96	·81	9·3	2·46
627	13—3–1956	17° 35·5′	83° 28·0′	0	33·24	·62	7·5	5·58
				8	34·78	·62	15·3	5·02
				23	34·60	·95	15·6	4·11
				31	34·92	1·12	20·0	3·83
				48	35·16	1·16	20·2	3·09
				60	35·16	1·52	27·5	2·90
696	24—4–1956	17° 38·2′	83° 30·2′	0	33·35	·51	7·5	3·74
				11	33·44	·61	7·8	3·03
				23	33·62	·83	8·1	2·89
				34	33·64	·94	10·6	2·87
				48	33·96	1·15	10·6	2·79
				59	34·05	1·12	10·9	2·18
715	4—5–1956	17° 34·5′	83° 28·5′	0	33·49	·41	9·4	4·18
				16	33·75	·58	10·6	4·18
				28	33·78	·60	10·7	3·64
				41	33·86	·61	11·9	3·33
				51	34·02	·64	12·5	2·48
				61	34·11	·69	12·8	2·18

face phosphate values showed an increase during March and April to as high as 1·52 μg. atoms. After this the concentration decreased to 0·69 in May.

The silicates are more variable but showed a general increase at all depths from October to May with a maximum peak of 27·5 μg. atoms at 60 metres depth in March. In other months the values ranged from about

9 to 14 μg. at 60 metres. It can also be seen from the table that salinities, phosphates, and silicates all increase with depth.

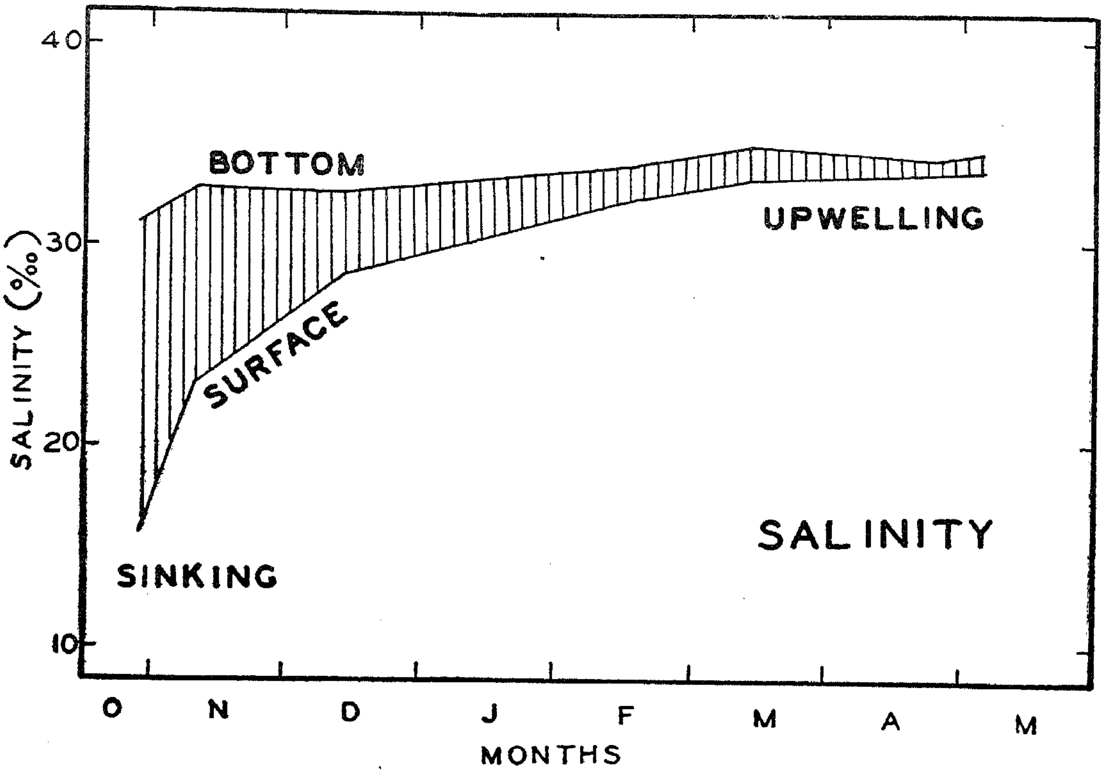

FIG. 1. Comparison of surface and bottom salinity off Waltair during the period of sinking and upwelling. (See table for location of stations from which the data were taken.)

The dissolved oxygen content was at a minimum during the fall months (2·4 to 4·0 ml./L.) and increased to the highest in March (5·6 ml./L.), as do the other three variables. In all cases the water is not saturated and the oxygen concentration decreases with depth.

DISCUSSION

Both the horizontal and vertical currents in the Bay of Bengal must be considered in explaining the chemical composition and its seasonal changes. From January to July the current flows in a general north-east direction, and from August to December the flow is reversed. In addition, there is a vertical displacement of water near the coast. That is, during October and November a shoreward or sinking motion is observed whereas in March and April this circulation is reversed and upwelling occurs. All these, together with the utilization of nutrient salts by organisms, influence the chemical composition.

Salinity, for example, shows a large difference from surface to bottom during the period of sinking (see Fig. 1). This is attributed to the influx of fresh-water from no less than 6 large and other small rivers to the north. The fresh-water remains at the surface because of its lower density thus creating the large vertical salinity gradient. This Northern Dilute water is also deflected towards the shore where the sinking is maximum. The later increase of both the surface and bottom salinity is the result of the influx of highly saline Southern Bay of Bengal water as the runoff subsides and the currents reverse in January. This is further affected by the upwelling of deeper and still more saline water during March and April.

The phosphate increase during March and April can also be attributed to the upwelling, which brings up the higher concentrations to shallower depths, where they can be utilized by phytoplankton. The increased planktonic production and utilization is reflected in the lower phosphate values in May.

The general increase of silicate at all depths from October to May may be attributed to the reduction of fresh water runoff, its replacement by Southern Bay of Bengal water, and by upwelled deeper layers. Although utilized by plankton, the advected water, especially by the March upwelling, appears to keep the water nourished. The regeneration by bacteria must also aid the silicate concentration in late spring.

The high values of the dissolved oxygen content of 5·58 ml./L. at the surface are due to photosynthetic activity during the season of upwelling. The low concentration from October to February reflects the reduced production. Likewise, the lower values of 2·7 to 4·2 ml./L. during May is probably due to the replacement of phytoplankton by the zooplankton. In all cases the water is not saturated.

SUMMARY

The chemical composition of the shelf water has been investigated and examples of the vertical chemical structure are given in the table. From these values and other related hydrographic information the chemical factors controlling the composition of the shelf water may be discussed.

The range of salinity between surface and bottom was greater during the period of sinking and lower during upwelling. The high values of salinity, phosphate, silicates and oxygen were influenced by upwelling. The advection of Northern Dilute water and Southern Bay of Bengal water also affect the vertical and horizontal chemical structure of the water. These were further modified by planktonic consumption during periods of accelerated production. A detailed report is under preparation.

REFERENCES

1. Ganapati, P. N. and Murty, V. S. R. "Salinity and temperature variations of the surface waters off Visakhapatnam Coast," *Andhra University Memoirs in Oceanography*, 1954, **1**, 125–41.
2. Ganapati, P. N. .. "Hydrography and phytoplankton in the inshore waters off Visakhapatnam," *Indian Jour. Fish.*, 1955, **2**, 84–95.
3. La Fond, E. C. .. "On upwelling and sinking off the east coast of India," *Andhra University Memoirs in Oceanography*, 1954 *a*, **1**, 117–21.
4. ———— .. "Environmental factor affecting the vertical temperature structure of the upper layers of the sea," *Ibid.*, 1954 *b*, **1**, 94–101.
5. Robinson, R. J. and Thompson, T. G. "The determination of phosphates in sea-water," *Journal of Marine Research*, 1948, **7**, 33–39.
6. ———— .. "The determination of silicate in sea-water," *Ibid.*, 1948, **7**, 49–55.