

## Arsenic Content in Waters of Parts of the Northern Indian Ocean

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Survey of total arsenic concentrations was carried out to evaluate the extent and magnitude of its occurrence in the waters of the Bay of Bengal, Gulf of Mannar and south-eastern Arabian Sea. Concentration of total inorganic arsenic varied from <1 to 18.75 µg/litre (av. 2.55 µg/litre). Arsenic concentration was highest in the Gulf of Mannar. It was found to be below the limit of detection in the oxygen minimum layer.

INCREASED interest in environmental studies has resulted in considerable attention being devoted to pollution caused by toxic heavy metalloids added by industrial effluents. Arsenic, a toxic metalloid, used in industry and agriculture, ultimately finds its way into the sea, thereby disturbing the natural balance of the marine environment.

The present paper is the result of a study of total soluble inorganic arsenic in the Bay of Bengal and adjacent regions, and is based on the observations made during a cruise of *INS Darshak* in March and April 1975. Values of total soluble inorganic arsenic from various depths at 12 stations in the western Bay of Bengal, 2 in the Gulf of Mannar and 4 in the south-eastern Arabian Sea are reported.

Samples were collected from the standard hydrographic casts at all stations, using TPN water samplers (type Hydro Bios, Kiel, West Germany), and stored in polythene bottles. They were subsequently analysed for soluble inorganic arsenic in the shore laboratory using the method of Johnson and Pilson<sup>1</sup>.

The standard deviation of the analyses was observed to be ±7%.

Stations from where samples were collected along with arsenic values are given in Table 1. Arsenic content in the northern Indian Ocean did not show much variation with depth except near the bottom at some stations.

In general, the values varied between <1 and 18.75 µg/litre (av. 2.55 µg/litre). The average reported value for sea water (Indian Ocean) is 3 µg/litre<sup>2</sup>. The values observed here are quite comparable with those reported from other areas. Arsenic concentrations ranging between <1 and 43 µg/litre have been reported in inshore waters of Goa (Central West Coast of India)<sup>3</sup>. These high arsenic concentrations may be due to land drainage. Distribution of arsenic in the open oceanic waters seems to be more uniform and regular in nature than that in the inshore waters where the proximity of land introduces complexity in the pattern of distribution of this element. It appears to be more dependent on the general circulation and sources of origin of different water masses.

Concentrations of 'surface water' (surface water stands for the waters above the depth of the

TABLE 1 — CONCENTRATION OF TOTAL SOLUBLE INORGANIC ARSENIC IN THE BAY OF BENGAL, GULF OF MANNAR AND THE ARABIAN SEA

Depth (m)	Total sol. inorg. As (µg/litre)	Depth (m)	Total sol. inorg. As (µg/litre)
St. 0191 [10°28'N, 83°27'E; 20.3.75]			
25	8.25	800	ND
50	6.75	1000	ND
75	1	1200	ND
100	ND	1500	ND
150	ND	2000	18.75
200	ND	2500	18.75
300	ND	3000	17.25
600	ND	—	—
St. 0192 [13°15'N, 84°34'E; 21.3.75]			
0	1	600	4.5
25	1	700	7.5
50	8.25	800	9.75
75	11.25	1000	ND
100	6.75	1200	ND
150	9.75	1500	ND
200	9	2000	3.75
300	ND	2500	5.25
400	1.5	3000	5.25
500	3	—	—
St. 0193 [16°22.5'N, 86°11'E; 22.3.75]			
0	1	400	3.75
25	1	500	1.5
50	1	600	2.25
75	1	800	6
100	3	1000	6
150	1	1200	5.25
200	2.25	1500	4
300	1.5	2000	11.25
St. 0196 [20°12'N, 88°01'E; 27.3.75]			
0	3	150	ND
25	3	400	ND
50	3.75	500	ND
75	2.25	600	ND
100	ND	700	6
St. 0197 [19°15'N, 86°58'E; 28.3.75]			
0	3.75	300	ND
25	6	400	ND
50	6	500	ND
75	4.5	800	ND
100	1	1000	ND
150	2.25	1200	1
St. 0198 [18°05'N, 85°53'E; 28.3.75]			
0	ND	400	ND
25	1	600	1.5
50	1	800	1
100	1	1000	1
150	ND	1500	1
200	ND	2000	1
300	ND	—	—
St. 0199 [17°01.5'N, 84°45'E; 29.3.76]			
0	1.5	500	ND
25	5.25	600	ND
50	3.75	700	ND
100	6.75	800	ND
150	5.25	1200	ND
200	5.25	2000	6
400	6.75	—	—

TABLE 1 — CONCENTRATION OF TOTAL SOLUBLE INORGANIC ARSENIC IN THE BAY OF BENGAL, GULF OF MANNAR AND THE ARABIAN SEA — *Contd*

Depth (m)	Total sol. inorg. As (µg/litre)	Depth (m)	Total sol. inorg. As (µg/litre)
St. 0200 [15°35'N, 83°10'E; 29.3.75]			
0	3.75	700	ND
25	2.25	1000	ND
50	2.25	1200	ND
200	ND	1500	ND
400	ND	2000	ND
500	ND	—	—
St. 0201 [12°01'N, 80°35'E; 4.4.75]			
0	1.5	500	ND
75	3.75	600	ND
100	ND	700	ND
150	ND	800	ND
300	ND	900	2.25
400	ND	1000	2.25
St. 0202 [10°40'N, 81°06'E; 5.4.75]			
0	ND	700	ND
50	1	800	ND
100	3	1000	1.5
200	3.75	1200	2.25
300	2.25	1500	2
500	4.5	2000	2.25
St. 0203 [09°32.4'N, 81°21'E; 5.4.75]			
0	4.5	600	1
25	6.75	700	2.25
50	3	800	2.25
75	ND	1000	11.25
100	1.5	1200	11.25
150	4.5	1500	9
200	1	2500	9.75
300	1	3000	8.25
400	1.5	—	—
St. 0204 [08°43.5'N, 81°35.5'E; 6.4.75]			
0	ND	600	2
25	1.5	700	3.75
50	1.5	1000	1
75	1	1200	1
100	2.25	1500	1.5
150	1	2000	1
300	1.5	—	—
St. 0205 [06°30'N, 79°00'E; 7.4.75]			
0	2	500	2.25
25	4.5	700	1.5
50	5.25	800	3.75
100	4.5	1200	7.5
150	2.25	1500	6.75
400	1	2000	9
St. 0206 [07°15'N, 78°03.5'E; 8.4.75]			
0	6.75	400	1
50	5.25	600	3
75	6	700	1.5
100	3	800	ND
150	1.5	1000	ND
200	1	1200	ND
300	1	1500	ND

TABLE 1 — CONCENTRATION OF TOTAL SOLUBLE INORGANIC ARSENIC IN THE BAY OF BENGAL, GULF OF MANNAR AND THE ARABIAN SEA — *Contd*

Depth (m)	Total sol. inorg. As (µg/litre)	Depth (m)	Total sol. inorg. As (µg/litre)
St. 0207 [08°01'N, 76°17'E; 8.4.75]			
0	ND	400	ND
25	6.75	800	ND
50	3.75	1000	1
100	ND	—	—
St. 0208 [09°12'N, 75°38'E; 9.4.75]			
0	2.25	200	ND
25	3.75	400	ND
50	1.5	600	5.25
100	ND	800	3
150	ND	—	—
St. 0209 [10°20'N, 75°20'E; 9.4.75]			
0	3	200	ND
25	ND	400	ND
50	ND	600	ND
75	ND	800	ND
100	ND	1000	ND
St. 0210 [11°17'N, 74°12'E; 9.4.75]			
0	3	200	1.5
25	1	400	1
50	1.5	600	3.75
75	1	800	6.75
100	1	900	5.25

ND = not detectable (<1 µg/litre).

thermal discontinuity layer) varied between <1 and 8.25 µg/litre whereas that of 'bottom water' varied from <1 to 18.75 µg/litre. That arsenic goes into the sediments by way of precipitation and adsorption is indicated by the presence of low values in bottom waters. High arsenic concentrations in the surface waters at station 0192 may be due to active recycling of the element. Arsenic re-enters the water column either by dissolution from the sediments or as a result of mixing by currents<sup>4</sup>. Fish and plankton are also known to play an active role in the arsenic cycle. On death and decay, the plankton and fish settle to the bottom where the arsenic is passed on to the sediments or is recycled depending upon the physical and chemical conditions.

In general, arsenic concentrations in the surface and bottom waters of the Arabian Sea are less than those in the Bay of Bengal and Gulf of Mannar. This may be due to a greater adsorption of arsenic into the fine clay particles in the Bay of Bengal and Gulf of Mannar. This difference in the surface waters may also be due to night and day observations.

Most of the not-detectable values (ND) of arsenic appear to be in the oxygen minimum layer. From Fig. 1 it can be seen that arsenic concentration appears to have a direct relationship with the

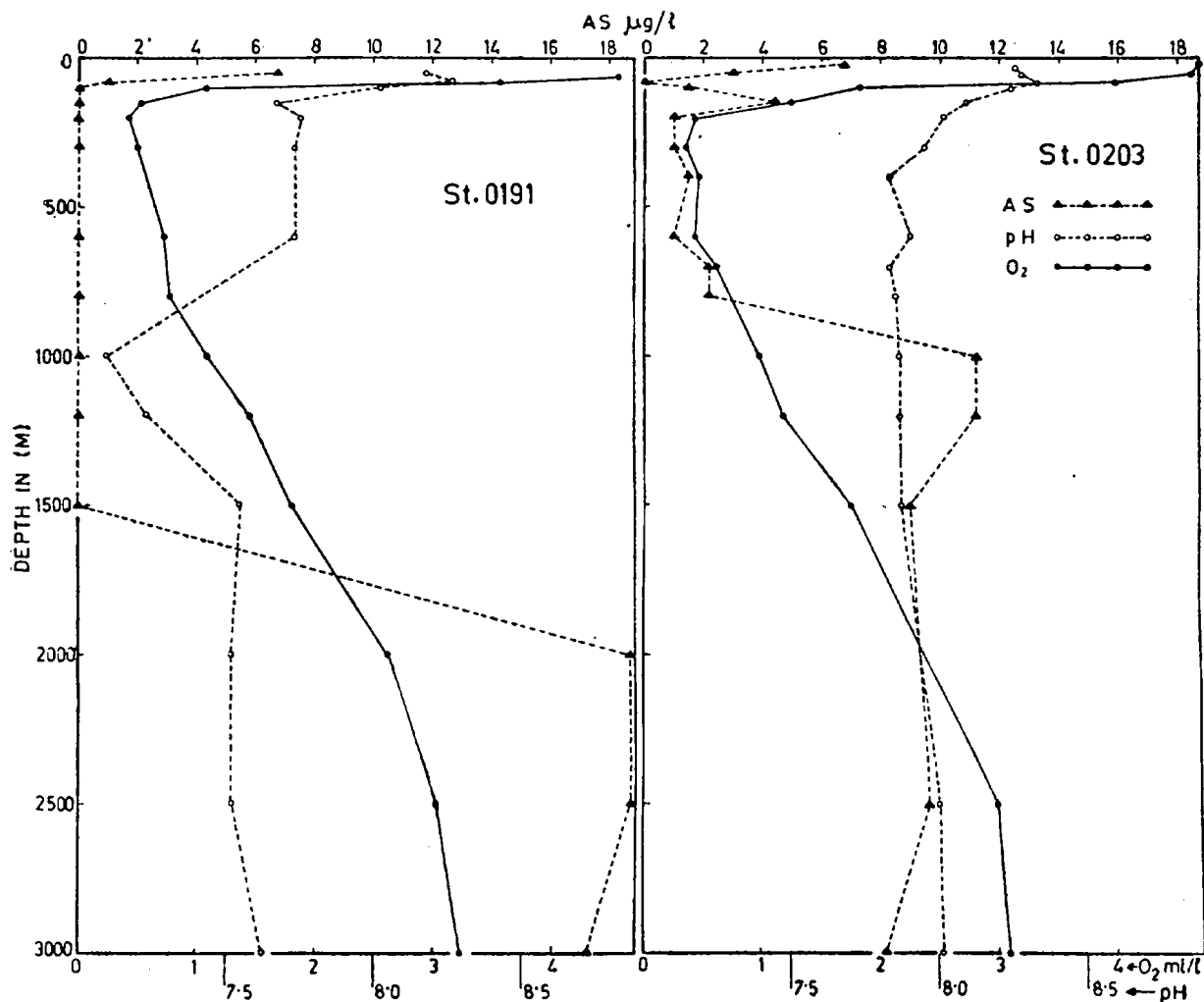


Fig. 1 — Vertical distribution of  $O_2$ , pH and As at stations 0191 and 0203

oxygen content. In surface waters, the arsenic content is more, whereas it decreases in the oxygen minimum level and again increases along with the oxygen content in the bottom waters. In presence of low oxygen, arsenic may be transformed into particulate or organic forms which again goes into the solution along with the increase in the oxygen content.

Arsenic exists in 2 inorganic forms as arsenate ( $As^{5+}$ ) and arsenite ( $As^{3+}$ ). It mainly occurs as arsenate in the Indian Ocean<sup>5,6</sup>. The ionic product of arsenate was found to be more in the bottom waters ( $5.45 \times 10^{-36}$ ) than in the surface waters ( $0.92 \times 10^{-36}$ ). This shows that at greater depths, solubility of arsenate increases and it may be released from the particles into the water. Since in the sea water, arsenate is predominant, the presence of total arsenic increases with depth. Thus it can be concluded that arsenic, as arsenate, is absorbed or assimilated in the surface layers of the oceans. Whatever arsenic is left in the water column would be mostly in the arsenite form.

Both arsenite and arsenate are removed from the water probably as particulates, at the intermediate depths. This process is regulated more by the availability of oxygen than by pH, as is evident from Fig. 1. Close to the bottom arsenic seems to get regenerated from both arsenite and arsenate.

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