

WATER QUALITY OF THE RIVERS MANDOVI AND ZUARI DURING 1977-78

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ABSTRACT

A study over a period of twelve months for the different indicators of water quality was carried out in the rivers Mandovi and Zuari from October 1977 to September 1978. The study covered observations in both the rivers from close to the source to the sea. To delineate the recipient capacities for sewage and effluents, the stretches of the rivers upto the last loading points for ores have been considered; while to judge their suitability as sources for raw water for public water supply only the zone, which is beyond the extreme point of penetration of the salt front, in the rivers has been examined in detail.

Comparisons of conditions in the rivers Mandovi and Zuari with the prescribed tolerance limits for industrial effluent discharge into inland surface waters were made and it was observed that except the total suspended solids, oils and grease, the rest of the components are well within the maximum tolerance limits in the ISI standard.

To test the water quality as sources for municipal raw water supply, some of the relevant components in the freshwater zones of the rivers were compared with WHO, USPHS, ICMR and ISI maximum allowable concentrations for such purposes. Occasional high values of calcium and magnesium, which are normally considered as marine contributions to inland rivers, were observed. Of the riverine components, excepting BOD₅, phenolic compounds and oils and grease, the rest were well within the limits of all the standards. Excepting BOD₅, which is an indicator of non-industrial addition to rivers, all the other components, whose values occasionally got beyond the tolerance limits, originate due to mining activities.

It has been concluded that both the rivers have a fairly good water quality as at present. But adequate measures have to be adopted to reduce or at least to maintain the present level of concentrations of all the components. This should be carried out by establishing a regular monitoring network as a safeguard to maintain the present quality of water of the two rivers.

INTRODUCTION

Since the liberation of the territory of Goa, Daman and Diu in December, 1961, this territory has undergone much change both industrially and agriculturally. The two rivers Zuari and Mandovi being the life-line of Goa, it can be expected that maximum development will take place along these two river basins. These two river basins cover an area of about 2,500 km² which is about 68% of the total land area of the territory of Goa. The population in these basins is around 470,000 or about 55% of the total for this territory. About two-thirds of the total production of iron, manganese and ferromanganese ores come from the mines located on these two river basins. Naturally major part of industrial activities in the territory are concentrated here as well. Moreover, because of its scenic beauty and unspoilt nature, Goa has a vast potential for development of tourism.

With the basic aim in view, that the two rivers are to be kept least polluted, an extensive survey was undertaken in the two rivers to prepare a master plan for pollution control. Earlier to this work, several different characteristics of the rivers Mandovi and Zuari have been examined, but most of them pertain to estuarine regions (Singbal 1973; Untawale, Dwivedi and Singbal 1973; Goswami and Singbal 1974; Singbal 1976). The objectives of the present work were to determine the existing water quality of the rivers Mandovi and Zuari in order to judge their eventual recipient capacities and to compare some relevant components from freshwater zones with WHO, USPHS, ICMR and ISI maximum permissible concentrations.

Description of the study area

The rivers Zuari and Mandovi (Fig. 1) can be called the "life line" of the union territory of Goa. They are mainly used as waterways to transport enormous quantities of iron and ferromanganese ores in barges to the harbour at Mormugao throughout the year. They are also used for fishing activities, practically throughout the year and particularly during the monsoon months when the sea fishing gets suspended.

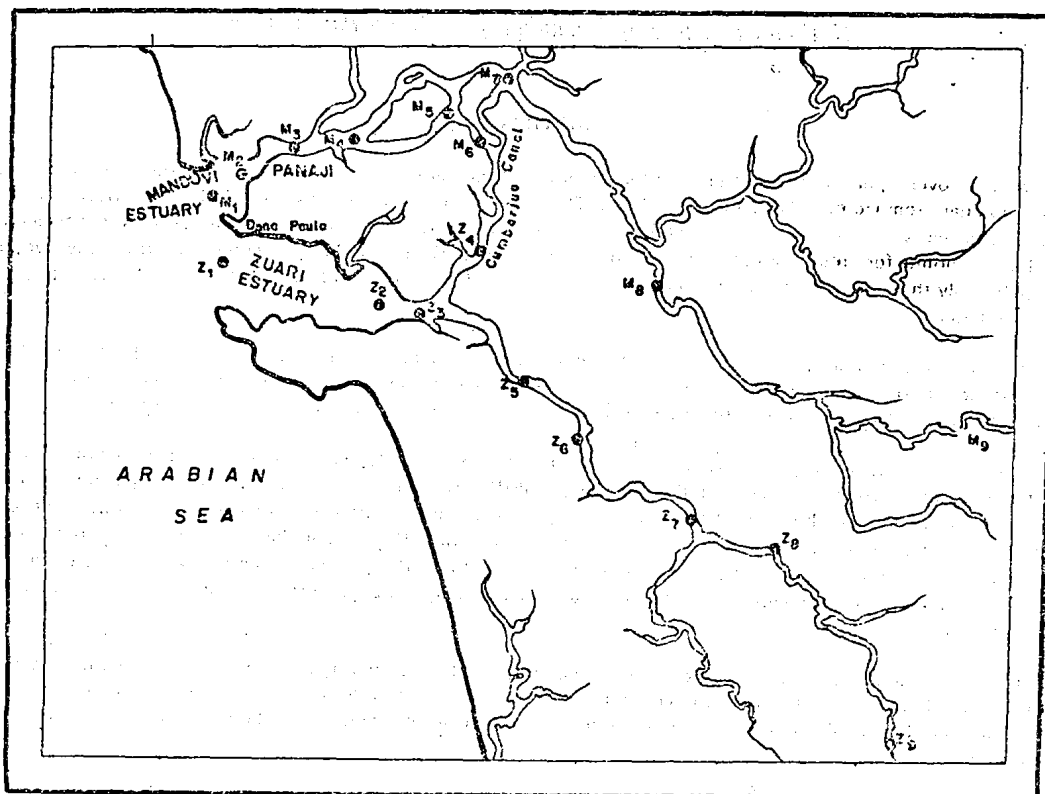


Fig. 1. LOCATION OF STATIONS
(SKETCH MAP)

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River Zuari originates from the Dighi Ghat of the Karnataka part of the Sahyadri hills and after flowing through a stretch of about 67 km meets the Arabian Sea near the Marmugao-Dona Paula point. Its width at the mouth of the estuary is 5.5 km while, it narrows down to less than 0.5 km. It is fed by monsoon precipitation and also receives discharge from a catchment area of about 550 km².

River Mandovi originates from the Parwa Ghat of the Karnataka part of the Sahyadri hills and after traversing a stretch of about 70 km joins the Arabian Sea through the Aguada Bay near Panaji. Its width at the estuary is 3.2 km while, upstream, it narrows down to 0.25 km. Like the Zuari river it is also fed by monsoon precipitation from the discharges from a catchment area of about 1,150 km².

MATERIAL AND METHODS

Seven stations (Fig. 1) were fixed in each of the two rivers. These stations took into consideration of the salt front and consequently the tidal influence and their nearness to the areas of mining industrial and domestic activities. One station was fixed at the uppermost reaches of each river as a control station. Moreover, two stations were fixed in the Cumbarjua canal, 10 km apart, at distances of 3 and 4 km from its openings into the Mandovi and Zuari rivers respectively. The total distance covered in between the 7 stations in the Zuari was 43 km plus additional 24 km between the upper two stations.

Observations were made once every month at mid-depth at all the stations every 3 hours. The parameters discussed here are colour, coliform organisms, pH, chlorides, dissolved oxygen, BOD, phenolic compounds, nitrates, oils and grease, iron, manganese, calcium, magnesium, arsenic, chromium, cyanides, selenium and mercury.

Standard methods were adopted for the analysis of different parameters described elsewhere (ISI 1964 ; APHA 1967 ; Carritt and Carpenter, 1966 ; Riley and Taylor 1968 ; Culkin and Cox 1966 ; Murphy and Riley 1962 ; EPA 1976 ; HMSO 1972 ; Gardiner and Riley, 1974).

RESULTS AND DISCUSSION

Effluent Discharge

Zuari basin is populated by 224,000 persons comprising 27% urban and 73% rural population. The corresponding figures for Mandovi basin are 246,000 and 29% and 71% respectively. Population-wise, therefore, the difference between the two basins is not significant.

In the absence of any data for communal sewage for the whole area, the known figures for central Panjim have been extrapolated for the entire urban population of both the basins. The rate in the rural areas has been assumed to be half of that from the urban area. A population of 40,000 persons in the central Panjim gave rise to 1,307.556 million litres of sewage in 1977-78 or 90 litres/person/day. The rate for rural area would be about 45 litres/person/day. Using these figures the annual contribution of sewage to the Zuari and Mandovi river systems would be 4.67 and 5.21 million cubic metres respectively.

In the Zuari basin there are 6 large, 13 medium and 110 small industries and their effluent discharge is approximately 4.4×10^6 m³/year. In Mandovi basin there are 4 large, 5 medium and 99 small industries and effluents of the order of 0.8×10^6 m³/year. This clearly indicates that the industrial activity is far more intense in the Zuari basin than in the Mandovi basin.

About 18% of the total geographical area of Goa is estimated to have mineral deposits. One third of this (260 concessions/lease) is being exploited at present. Of the concessions given, only 37 large mines produce two-thirds of the total production of iron, manganese and ferro-manganese ores. Ten of the large mines are located in the Zuari basin while the remaining 27 are in the Mandovi basin. These mines discard 1,000-6,000 tonnes of waste per mine per day. It is thus apparent that the mining activity is twice more intense along the Mandovi basin than Zuari basin.

River Zuari is navigable upto 62 km from its mouth while the last loading point on it is located at a distance of 50 km (close to station Z8).

River Mandovi is navigable only upto a distance of 42 km from its mouth where the last loading point on it is also located (close to station M8).

Most of the developmental activities, therefore, along the two river basins are at present restricted to the navigable distances from their mouths. The existing water quality in these rivers between the stations Z1 and Z8 and between M1 and M8 with the standards for effluent discharge into rivers, given by the ISI, is of considerable interest for future planning.

TABLE - 1

Comparison of conditions upstream in the rivers Zuari and Mandovi with tolerance limits for inland surface waters for use for public water supply

Sl No	CHARACTERISTIC	MAXIMUM ACCEPTABLE CONCENTRATION				River Zuari	River Zuari	River Mandovi	River Mandovi
		WHO	USPHS	ICMR	IS 2296	SANVORDEM (Zg)	NETURLIM (Zg)	USGAON (Mg)	COLEM (Mg)
1	COLOUR NZU	5	15	25	-	8-45	2-32	2-23	4-28
2	Coliform organisms MPN/100 ml	-	-	-	not more than 5000	3-1100	0-1100	0-1100	0-1100
3	pH	7.0-8.5	-	7.0-8.5	6.0-9.0	6.4-7.8	6.0-6.9	6.1-7.7	6.5-7.5
4	Chlorides (mg/l)	200	250	250	600	0-33	0-30	0-10	0-7
5	Dissolved Oxygen ml/l	-	-	-	3	6.2-8.2	6.4-8.1	5.1-8.7	5.1-8.6
6	BOD ₅ mg/l	-	-	-	3.0	0.8-3.8	0.6-3.2	0.9-3.8	0.8-4.2
7	Phenolic Compounds (mg/l)	0.001	0.001	0.02	0.005	0-0.01	0-0.01	0-0.01	0-0.01
8	Nitrates (mg/l)	-	45	20	50	0.06-0.26	0.04-0.16	0.02-0.30	0.02-0.14
9	Oils and grease (mg/l)	-	-	-	0.10	0-4.1	0-3.6	0.3-6.2	0.8-5.8
10	Iron (Fe) mg/l	0.3	0.3	0.3	-	0-0.04	0.01-0.23	0.01-0.03	0.01-0.03
11	Manganese (Mn) mg/l	0.1	0.05	0.1	-	0.09-0.03	0-0.04	0-0.02	0-0.03
12	Calcium (Ca) mg/l	75	-	75	-	3.80-178	3.40-7.90	5.0-4.6	4.0-10
13	Magnesium (Mg) mg/l	50	-	50	-	0-457	0-6.1	0-72	0-15
14	Arsenic (As) mg/l	-	0.05	-	-	0-0.01	0-0.01	0-0.01	0-0.01
15	Chromium (Cr ⁺⁺⁺) mg/l	-	0.05	-	-	0-0.07	0.06-0.01	0.03-0.01	0-0.03
16	Cyanides (Cn) mg/l	-	0.01	-	0.01	0	0	0	0
17	Selenium (Se) mg/l	-	0.01	-	0.05	0-0.01	0-0.9	0-0.01	0-0.01
18	Mercury (Hg) µg/l	-	-	-	-	0-12.0	0-15.8	0-112.5	0-108

(105)

Table 1 gives the existing conditions in the rivers in relation to WHO, USPHS, ICMR and ISI standards. The values have been presented as ranges observed from October 1977 to September, 1978.

Except for the total suspended solids, oils and grease all the other values are much below the maximum tolerance limits prescribed by the ISI. The total solids, oils and grease are evidently the results of mining activities.

Averaging the values for suspended solids at Z8 and Z9 and M8 and M9 for the observation period and combining them with the freshwater runoff in both the rivers the figures of 112,000 and 136,000 tonnes are arrived at as the annual addition of suspended solids in the upper reaches of Zuari and Mandovi respectively. Treating the values at Z1 and M1 the same way the final figures for the annual additions of suspended solids from the Zuari and the Mandovi rivers into the sea become 187,000 and 531,000 tonnes respectively. About 20% of this gets precipitated in the estuarine and 10% in the nearshore regions where the river water meets the sea water. This means that about 500,000 tonnes of suspended solids are added to the sea every year from these two rivers of Goa. The waters from the Mandovi are far more loaded with suspended solids, as compared to the Zuari waters during their flow from the upper reaches to the sea.

Oils and grease are contributed to the rivers by the industrial and domestic wastes. However there is another source for oil and grease coming from mining activities. About 100 - 250 kg grease are used per mine per month.

Thus, it can be concluded that both the rivers have a fairly high quality of water criteria and if adequate measures are taken to reduce or at least to maintain the existing load of suspended solids, oils and grease within the prescribed limits, the purity of water will continue to remain as it is at present in the two rivers.

Public Water Supply

At present there are only two pumping stations for the public water supply in Goa - Opa Water Works along the Khandepar river and the Assonora Water Works along the Assonora river. Both these rivers are the

tributaries of the River Mandovi and the two pumping stations together have the installed capacity of pumping 31×10^6 m³ raw water every year. Another project - the Salaulim Irrigation Project on the River Zuari is being planned to supply raw water to a large area.

A comparison, therefore, between the present water quality from Z8 to Z9 and M8 to M9 with the ISI standard regarding the tolerance limit for the river water for public health purposes would be very appropriate. The values for those months when the chloride content of the water was greater than the maximum tolerance limit of 600 mg/l have been omitted.

TABLE - 2
Comparison of conditions in the rivers Zuari and Mandovi with tolerance limit for industrial effluent discharge into inland surface waters (IS 2490- Part I, 1974.)

CHARACTERISTIC	IS 2490-1974 Tolerance limit	Range	
		River Zuari Mormugao Bay - Sanvordem (Z ₁) (Z ₈)	River Mandovi Aguada Bay - Usgeon (M ₁) (M ₈)
Total suspended solids mg/l	100	0.8 - 143*	0.2 - 136*
pH	5.5 - 9.0	6.1 - 7.9	6.1 - 8.2
BOD mg/l	30	0.4 - 7.7	0.2 - 5.6
Oils and grease mg/l	10	0.2 - 9.2*	0.3 - 8.2*
Phenolic compounds mg/l	1.0	0 - 0.004	0 - 0.011
Cyanides mg/l	0.2	0	0
Arsenic mg/l	0.2	0 - 0.041	0 - 0.02
Cadmium chromium mg/l	2.0	0 - 0.01	0 - 0.01
Hexavalent chromium mg/l	0.1	0 - 0.03	0 - 0.02
Mercury mg/l	0.01	0	0
Selenium mg/l	0.05	0 - 0.01	0 - 0.01
Ammonical nitrogen mg/l	50	0.02 - 0.1	0.01 - 0.2
COD mg/l	250	0.3 - 3.6	0.3 - 6.4

* Occasional higher values were observed.

SOURCE: Master plan for pollution control of the rivers Zuari and Mandovi (NIO Tech. Report 02/79)

10/5-2

Table 2 gives our observations along with the maximum tolerance limits prescribed by ISI. The values given in the table are in ranges at the stations from October 1977 to September 1978 excluding January - May 1978 for Z8 and for May 1978 for M8.

Excepting BOD₅, phenolic compounds and oils and grease, the rest of the components are well within the maximum tolerance limit of the ISI standard.

Though the upper limits of BOD₅ are only marginally higher than the prescribed standard, the values indicate higher concentrations of organic material of non-industrial origin. These could conveniently be removed by treatment before the water is pumped for the public supply.

The excess of oils and grease are the result of mining activities, as mentioned earlier and these could also be removed by pre-treatment.

The maximum values of phenolic compounds at the stations are about double the prescribed tolerance limit. Phenolic compounds are as a result of industrial and domestic wastes, originating from the industries, household needs and also from the explosives used in mining activities. In Goa 1000 - 5000 kg of explosives are used per mine per month. Higher concentration of phenolic compounds in the waters of Zuari and Mandovi may be the combined effect of these sources.

The station M8 was located on Khandepar river close to the Opa Water Works, Z8 was located on Zuari at Savordem and Z9 at Curadi, The Salaulim Irrigation Project lies in between these two stations. M9 was located at Collem in the freshwater region of the River Mandovi.

In conclusion it can once again be emphasized that regular monitoring of biochemical oxygen demand, oils and grease and phenolic compounds in the raw water used for the public supply is very essential to safeguard public health on a long term basis.

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