



ENVIRONMENTAL STUDIES NEAR MANGALORE FOR DISPOSAL OF INDUSTRIAL EFFLUENTS

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ABSTRACT

The physical characteristics of the waters of Gurpur River and New Mangalore Harbour were investigated during February 1979 to assess their suitability for the proposed disposal of effluents by Kudremukh Iron Ore Co., Mangalore. The data on currents (speed and direction), temperature and electrical conductivity were collected at 15 minutes interval for 25 hours continuously using Aanderaa recording current meters at few selected locations. Dispersion studies using Rhodamine -B dye were also carried out.

These studies showed likely accumulation of pollutants in these water bodies especially during non-monsoon months.

INTRODUCTION

The increasing awareness of the need to preserve and protect the nearshore and estuarine water bodies from being polluted due to indiscriminate discharge of effluents with varying contents and concentrations demand prior assessment on their suitability to receive the wastes particularly from the shorebased industries. To this end, various bodies, charged with the task of controlling pollution, set up at the central and state levels, insist on detailed investigations to be made on the water bodies into which the discharges are proposed by the industrial organisations.

Kudremukh Iron Ore Co. Ltd., Mangalore posed with the problem of disposing the effluents (at a rate of 500-700 m³/day) consisting mostly of fresh water with high pH, traces of sulphite and sulphate products, other dissolved materials including a polymer by trade name SEPARAN, some

heavy metals and suspended materials - all in a colloidal form into the estuarine system or harbour proper, requested the NIO to help in assessing the suitability of the waters of New Mangalore Harbour and the Gurpur River.

Earlier, the waters of Netravathy-Gurpur estuarine complex were studied for their seasonal variation of the hydrographic conditions by Suresh, Reddy and Kurian (1978) and Reddy, Hariharan and Kurian (1979) and the circulation pattern of the nearshore areas were investigated by Gouveia and Varadachari (1979) and Reddy, Kurian and Hariharan (1979). The present study, however, was undertaken specifically for the purpose of evaluating the suitability of these waters for disposal of effluents from KIOCL, Mangalore during the pre-monsoon months which represent extreme conditions from the point of view of fresh-water discharges aiding either dilution or dispersal of the released effluents.

MATERIALS AND METHODS

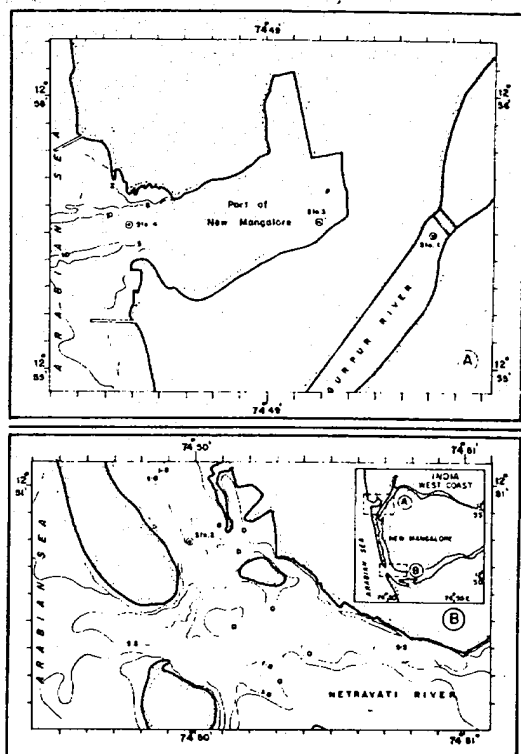


Fig.1 New Mangalore Harbour (A) and the Gurgur-Netravathi confluence (B), showing station positions. Contours shown are in metres.

Of the four locations (Fig. 1) investigated, Stations 1 and 3 represent the proposed sites for effluent disposal by the KIOCL. Stations 2 & 4 were selected as they represent the prevailing conditions at the entrance to the two water bodies. Operations at stn. 1 were conducted using a country craft as the river is very shallow. The currents at near surface were measured with the help of a float. Water sampling at 1m and 4m depths was carried out using a Nansen bottle fitted with reversing thermometers, at intervals of 3 hours for 25 hours. Temperature was noted immediately and salinity was determined by a salinometer. Data on currents at different depths at station 4, collected earlier (during 1977) by New Mangalore Port authorities, are utilised for purpose of discussion.

As the depth at station 2 was about 2.5m only, one Aanderaa recording current meter was operated at 1m above the bottom, while

at station 3, where the depth was about 7.5 m, two Aanderaa current meters were used, at 1.5m and 6.5m above the bottom.

The Aanderaa recording current meter used for the study has two main parts : one - recording unit and two - a vane assembly. This self-contained instrument records temperature, conductivity, pressure, current speed and direction at selectable intervals of time on a $\frac{1}{4}$ inch magnetic tape. The current speed is sensed by a savonius type rotor, direction by a magnetic compass coupled to a potentiometer, temperature by a thermistor and conductivity by an inductive type sensor. The instrument gives an accuracy $\pm 0.15^\circ\text{C}$ in temperature, $\pm 0.1\%$ in measured conductivity and depth, $\pm 2\%$ of the actual speed and $\pm 5^\circ$ in direction. The threshold speed of the speed sensor is 2.0 cm/second. Salinity was calculated from the observed conductivity and temperature using the formulae given by Bennett (1976).

At stations 1, 2 & 3 about 250 g of Rhodamine B dye was mixed with 5 litres of water and introduced in the surface layer during the high and low water slack times. The dye patch was tracked and sampled at fixed intervals till the patch disappeared. The dye concentration was analysed by a colorimeter.

The data on current speed and direction sampled at 15 min. interval for 25 hours were analysed for the resultant (mean) current velocity. The observed current in the area, u can be considered as a sum of the (mean) resultant current \bar{u} , a tidal component U and a random component u' i.e.

$$u = \bar{u} + U + u' \quad \dots (1)$$

$u - \bar{u}$ were found for individual observations and are sum of tidal oscillations and the random fluctuations. The corresponding speed and directions were obtained for a comparison with the observed speeds and directions.

RESULTS

The tides near Mangalore are of a mixed, predominantly, semi-diurnal type with a maximum range of 1.5 m during spring solstices.

Gurpur River:

The results of the observations at station 1 are given in Table 1. Surface temperature varied from 29.5 to 31.0°C. Surface salinity varied from 16.6 to 23.9‰ while near bottom salinity variations were from 20.7 to 27.1‰. The maximum flood and ebb currents at the surface were about 30 cm/sec and 45 cm/sec. Directions changed up and down with flood and ebb. The upstream flow was of a shorter duration compared to the downstream flow.

The results of observations at station 2 are shown in Fig. 2. Time variation of

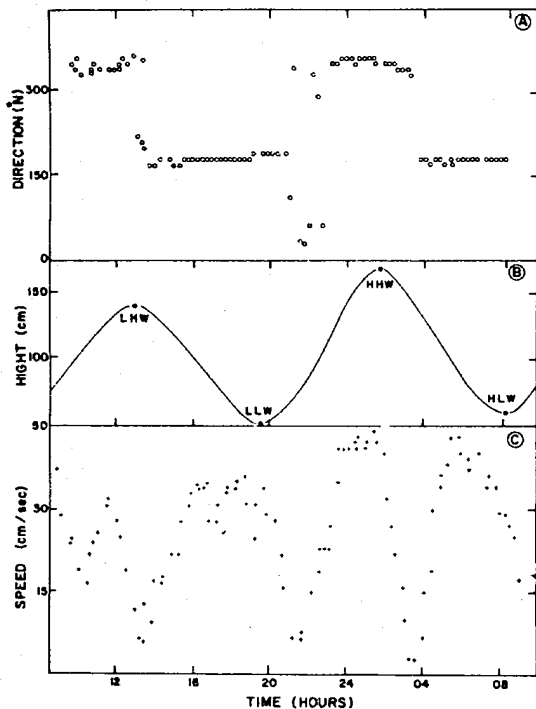


Fig. 2 Time variation of current direction tide and current speed at station 2.

current direction is shown in (A), tide in (B) and current speed in (C). The direction was either around 180°N or 350°N most of the time with a few exceptions during slack periods. The peak current during flood preceding LHW was 33 cm/sec. The ebb that followed had a peak value of 35.3 cm/sec. The peak current during the

flood flow from LLW to HHW was 44.3 cm/sec. The ebb current that followed had a peak value of 43.3 cm/sec. The peak flood currents coincided nearly with the times of highwaters, but peak ebb current occurred somewhere between high and low waters. Flood currents were comparatively of shorter duration than ebb currents. Slack waters occurred after corresponding high or low waters.

The mean currents \bar{u} at this station had a magnitude of 5.25 cm/sec, direction 193° N and constancy 19.7%. The computed $u - \bar{u}$ had a lower speed compared to u during the ebb flow and higher speeds during the flood flow. The computed directions were somewhat nearer to the observed directions.

The time variations of electrical conductivity, salinity and temperature are given in Fig. 3. The values of conductivity and

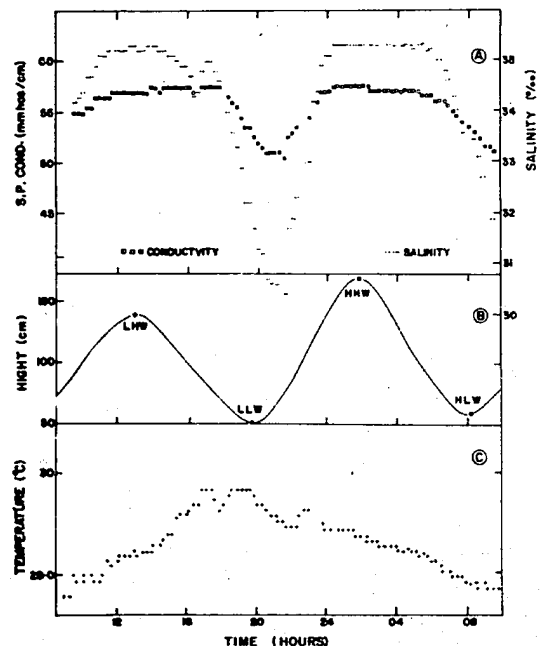


Fig. 3 Time variation of electrical conductivity, salinity, tide level and temperature at station 2.

salinity generally increased during flood tide, reached a peak value and remained nearly the same until ebb current almost reached its peak, when the values became as low as 50.4 m.mho/cm in conductivity (30.4‰ in salinity). Conductivity rapidly increased again to a high value of 57.4 m.mho/cm (35.3‰ in salinity) before the next high water.

The time variation of temperature shows a stronger influence of diurnal variation. Temperature increased steadily from 27.8°C at 0800 hr to 29.5°C at 1800 hr and thereafter decreased gradually to the initial value. However, it showed a decrease of about 0.2°C during the slack water corresponding to the LLW (see Fig.3).

New Mangalore Harbour:

The time variations of current directions with tide and current speeds at 6.5 m is given in Fig. 4.

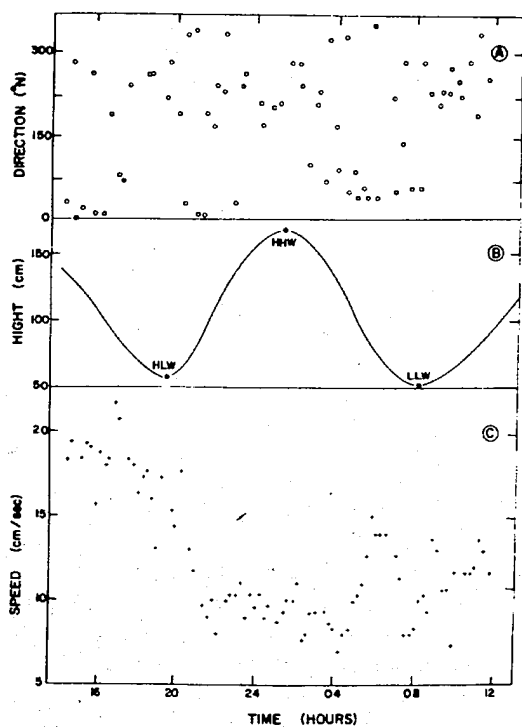


Fig. 4 Time variation of current direction, tide level and current speed at 6.5 m above bottom at station 3.

The direction and speed of current at 6.5 m above bottom showed considerable variations. Direction was around 40°N during ebbing. The speeds were around 18 cm/sec during the period 14 to 21 hr. This was traced partly to influence of diffracted waves entering the area. For the rest of observational period, speed had a peak value around 15.0 cm/sec during ebb flow and 13.6 cm/sec during flood flow. The resultant speed, direction and constancy at this depth were 3.6 cm/sec, 306°N and 28.8% respectively.

The directions and speeds corresponding to $u - \bar{u}$ were somewhat different from u . The computed speeds were slightly lower than the observed speeds for the period 14 to 21 hr and slightly higher for the rest of the period.

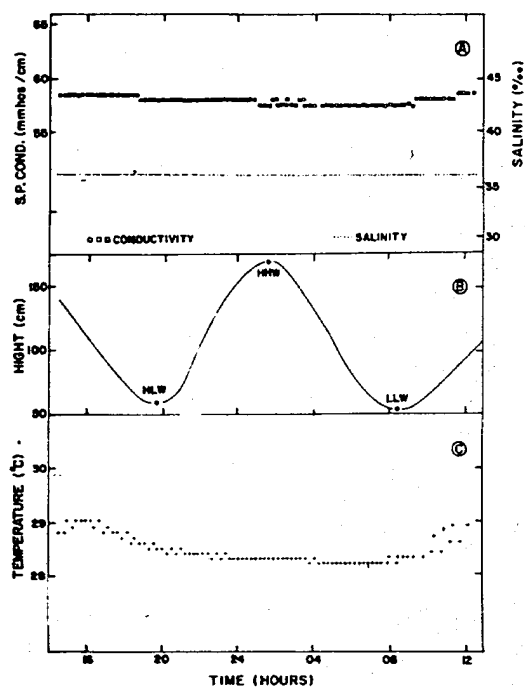


Fig. 5 Time variation of specific conductivity, salinity, tide level and temperature at 6.5 m above bottom at station 3.

Fig. 5 gives the observed variations in conductivity, salinity and temperature at this depth. Temperature was 29°C at 15.45 hr and decreased to 28.2°C at 08.30 hr,

corresponding to this there was a decrease in conductivity, so that salinity during the entire period was nearly the same, about 35.5‰.

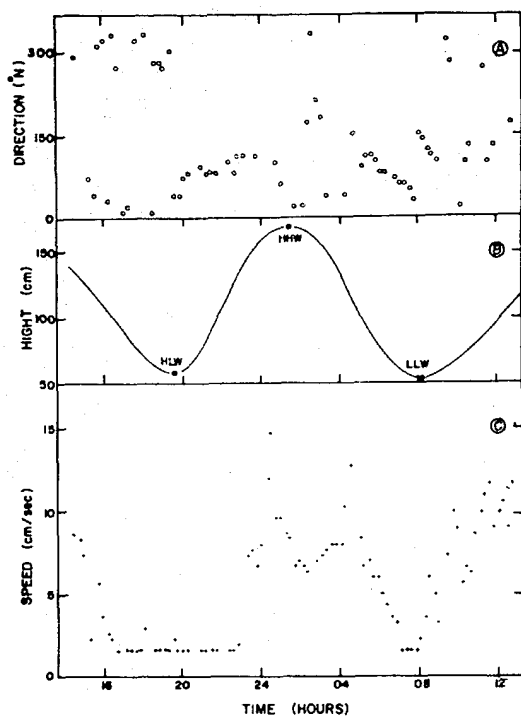


Fig. 6 Time variation of current direction, tide level and current speed at 1.5 m above bottom at station 3.

At 1.5 m above the bottom, directions generally varied between 0 to 150°N (see Fig. 6). The peak speeds were 14.7 cm/sec during the flood and 12.7 cm/sec during the ebb. The slack water corresponding to HLW lasted for more than 6 hours and there was only a short slack water corresponding to HHW. Again, the slack water corresponding to LLW was very short and current speed increased sharply after this. The resultant values at this depth were: speed - 1.58 cm/sec, direction - 75°N and constancy - 28.4%. The speed and direction corresponding to $u - \bar{u}$ showed some difference from the observed speeds and directions. The variations in temperature, conductivity and salinity at this depth were small (see Fig. 7).

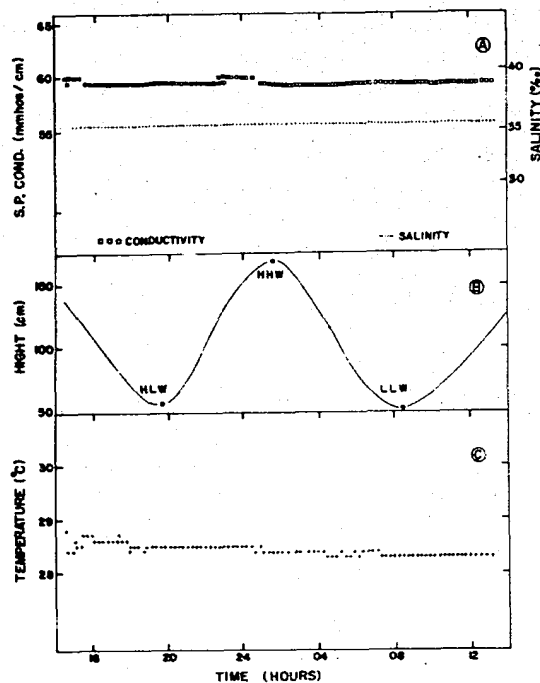


Fig. 7. Time variation of specific conductivity, salinity, tide and temperature at 1.5 m above bottom at station 3.

However, temperature showed a mild diurnal variation.

The data of time variations of components of currents into and out of the bay at station 4 are given in Table 2. Table 3 gives results of the dispersal studies using Rhodamine dye at stations 1, 2 and 3.

DISCUSSIONS

The general features of the studied water bodies are summarised below.

The tide in the Gurpur River was found to lag compared to the tide at Mangalore Harbour. The lag at station 1 was 30 minutes to 1 hour for high waters and 2 to 3 hours for low waters.

The temperature variations in these waters were more of diurnal nature.

The conductivity (salinity) values in the Gurpur River were very much dependent on the phase and range of tide. Salinity increased slowly with flood tide but decreased as much as 5‰ during ebb tide.

The resultant currents in the Gurpur River, as shown for station 2, were of the order of 5 cm/sec, in the down stream direction. Resultant currents at station 3 were only 1.6 to 3.6 cm/sec. The resultant direction near the surface was 306°N and near the bottom 75°N.

Samples of effluents supplied by the KIOCL contained traces of copper, cadmium, lead, mercury, nickel, zinc and arsenic. The dissolved solids in the effluent was only 70 - 160 mg/l. SEPERAN, when dissolved in water, gave a high viscosity. This was also found to decompose in water with a high pH.

Gurpur River;

The Gurpur River had all the characteristics of an estuary during the period of observation. Prediction of dispersion of pollutants in estuaries is a complex problem because of the oscillatory nature of the tidal current with unequal ebb and flood velocities, phase shift between velocities and range, variation of the geometry of sections of the estuary, stratification and vertical transport of pollutants. The discussions, therefore, will be based on simplified approaches to such problems as given by Bowden (1978) and Officer (1978).

In the case of an estuary, for one dimensional representation, the rate of transport of salt over a tidal cycle, $\langle F_x \rangle$ can be related to the longitudinal dispersion coefficient, D_x by

$$\langle F_x \rangle = A \left\{ u_0 S_0 - D_x \frac{dS_0}{dx} \right\} \dots (2)$$

where A is the average cross sectional area of the estuary, u_0 and S_0 are the average cross sectional mean velocity and

salinity over distance x. For steady state conditions, $F_x = 0$ and (2) becomes

$$D_x = u_0 S_0 / \frac{dS_0}{dx} \dots (3)$$

In the present case, assuming u_0 is of the order 5 cm/sec, $dx = 9.6$ km, $S_0 = 28.5‰$, $dS_0 = 1.8‰$ and D_x works out to be of the order of 11×10^6 . This is greater than values reported for in many other estuaries (see Officer, 1978).

Assuming further, the mouth of the estuary to be a perfect sink and using salinity as a tracer of water movements and dispersion effects, Officer (1978) expressed the fresh water fraction of water at any locality as

$$f = \frac{S_b - S_0}{S_b} \dots (4)$$

where S_b is the salinity of the coastal water, and S_0 is the observed salinity. If R is the river flow, and W is the rate of supply of pollutant (in mass/time), neglecting the water discharged with the pollutant

$$W = c_0 R \dots (5)$$

where c_0 is the cross sectional average pollutant per unit volume of sea water. If the fresh water fraction at the outfall is f_0 and up and down estuary distribution of the pollutants are given by

$$c_x = c_0 \frac{S_x}{S_0} \dots (6)$$

$$c_0 = c_x \frac{f_x}{f_0} \dots (7)$$

Under the same assumption, one dimensional mass and salt continuity equations may be written

$$A u_x = R \dots (8)$$

$$u_x S - D_x \frac{dS}{dx} = 0 \dots (9)$$

As shown by Officer (1978), we may re-write the pollutant continuity equation in the up and down directions as

$$0 = R_c - D_x A \frac{dc}{dx} \dots (10)$$

$$W = R_c - D_x A \frac{dc}{dx} \dots (11)$$

Though the pollutants may not behave either like salt content or freshwater, we can get an idea of its likely distribution from the distribution of salinity.

As river discharge decreases, say from January to May in Mangalore area, salinity of the river will increase and it seems possible that in addition to building up of pollutants at the outfall, less concentrated pollutants may move upstream during the non-monsoon months. Only during monsoon months, the pollutants are likely to be moved out of the estuary.

New Mangalore Harbour:

The new Mangalore Harbour is an artificial bay of approximate area of 10.69×10^5 square meters and a mean depth of 9.7 m below MSL and connected to the open sea through a channel of 225 m wide. In a simple case, where tide range reaches everywhere simultaneously and the entire cross section of the channel is utilized for the flow, according to Sverdrup et al (1942), the peak flow across the section (of area B) is

$$V = \frac{4 \pi A}{3 T B} 2n_0 \quad \dots\dots\dots (12)$$

where $2n_0$ is the range of the tide.

For this area with 1 m tide range and period, $T = 6.21$ hr, this works out to be only a few cm/sec. However, measured values are somewhat higher (see Table 3), indicating contribution from other effects.

At station 3, the resultant currents at 6.5 m and 1.5 m above the bottom were 3.6 cm/sec. The peak speeds were only 12 to 14 cm/sec. Average salinity value was about 35.5‰. The volume of water entering the bay corresponding to a tidal range of 1 m is of the order of $1 \times 10^6 \text{ m}^3$. This is about 1/10 of the total volume of water in the Bay and mixing within the bay is fairly weak as seen from the dispersion studies using Rhodamine dye (see Table 3). This leads to low dispersion of any effluent discharged in the area.

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TABLE 1
Variation in current, temperature and salinity over a period of 24 hours at station 1

Date	Time (hrs)	Surface Speed (cm/sec)	Current Direction	Temperature (°C)		Salinity (‰)	
				Surface	4 m	Surface	4 m
13.2.1979	10 15	17	Upstream				
"	12 30	10	"	30.5	30.2	19.82	21.38
"	13 30	10	Downstream				
"	15 30	33	"	31.0	30.4	23.74	24.59
"	16 30	30	"				
"	18 30	27	"	31.0	31.0	16.63	20.76
"	19 30	27	"				
"	22.15	7	Upstream	29.1	29.5	18.19	24.00
"	23 30	25	"				
						19.69	25.05
14.2.1979	00 30	21	"				
"	01 30	10	"				
"	02 30	11	Downstream	30.5	29.8	23.94	26.19
"	03 30	21	"				
"	04 30	46	"				
"	05 30	43	"	30.0	30.0	20.48	24.28
"	06 30	27	"				
"	07 30	26	"				
"	08 30	14	"	30.0	30.0	20.19	23.39
"	10 30	17	Upstream	30.5	30.0	19.44	27.10

TABLE 2

The observed currents at station 4 on 22.3.1977. The components perpendicular to the entrance Section are given, - sign indicates the flow is out-ward and + sign indicates it is into the bay.

Time (hr)	Tide (m)	Current speeds (cm/sec)			
		Surface	3 m	6 m	8 m
06 30	0.28	+ 19.9	+ 25.9	+ 26.0	+ 10.6
07 30	0.32	+ 28.6	+ 25.3	+ 25.4	+ 26.0
08 30	0.54	-	-	-	-
09 30	0.86	-	-	-	-
10 30	1.16	- 9.4	- 6.7	-	-
11 30	1.40	- 8.9	- 23.9	- 12.6	- 0.7
12 30	1.50	- 4.0	- 25.6	+ 24.9	+ 4.0
13 30	1.48	- 19.9	- 6.7	- 25.1	+ 1.4
14 30	1.40	- 23.6	- 40.2	- 0.0	- 14.7
15 30	1.20	- 26.0	- 34.2	- 34.2	- 13.4
16 30	0.96	- 41.4	- 25.2	- 15.0	- 1.1
17 30	0.77	- 20.4	- 29.9	- 11.0	+ 2.7
18 30	0.64	- 9.8	- 14.7	+ 18.9	+ 6.1
19 30	0.74	- 15.4	- 15.4	- 20.1	- 25.1
20.30	0.86	- 5.2	- 10.3	- 9.8	- 12.8
21 30	1.06	- 7.4	- 7.4	- 4.9	- 10.7
			- 10.2	- 14.2	- 20.1

TABLE 3

Results of dispersion studies at the stations using the Rhodamine dye

Time lapsed (minutes)	Station 1		Time lapsed (Minutes)	Station 2		Time lapsed (minutes)	Station 3	
	Concentration (mg/l)	Percentage of initial value		Concentration (mg/l)	Percentage of initial value		Concentration (mg/l)	Percentage of initial value
0	3.35	100	0	4.41	100	0	4.38	100
25	0.24	7.16	10	3.39	76.87	10	3.64	83.11
35	Beyond detection	5	20	0.72	16.33	23	0.64	14.61
			30	Beyond detection	5	33	Beyond detection	5