WATER QUALITY ANALYSIS AT STRATEGIC POINTS ALONG THE CHANNEL, AT "J" POINT AND AT UPSTREAM AND DOWNSTREAM OF IT.

CHAPTER - I

WATER QUALITY ANALYSIS AT STRATEGIC POINTS ALONG THE CHANNEL, AT "J" POINT AND AT UPSTREAM AND DOWNSTREAM OF IT.

Earth is a water planet as over 70% of its surface is covered by water. Most of it is the salt water of oceans, with fresh water upon which many terrestrial forms of animals and plants depend on, constituting only 3% of the total water on the planet. However, the net amount of fresh water is renewed by continuous cycling of water driven by the solar energy. The water evaporated by solar energy or by transpiration by plants is precipitated as rainfall and when it infiltrates the soil, it aids in plant production and recharge of ground water or, it may run off the surface into lakes, streams and rivers. The abundance of water on earth is not evenly distributed as, in many parts limited precipitation, high population density or both make the available fresh water less adequate or create substantial limitation to human needs. The greatest water stress is experienced by Asia and Africa with supply to each Asian country less than half the global average.

Water is very vital for man as it is much needed to feed the growing population, to produce material goods that raise living standards and also to preserve the integrity of natural system on which life sustains. The scarcity of such a fundamental natural resource is bound to have serious consequences and disrupt economic and social activity. The marine and estuarine waters apart from supporting characteristic life are also of great economic value to mankind. The quality of water is of great importance on both these aspects. With population growth and rapid urbanization and industrialisation, environmental pollution especially of the aquatic environment is becoming more critical. In this respect, pollution of coastal and estuarine waters which offer greater hopes of future food supplies to mankind is also not exempt. Pollution problems increase as populations move to the coast in search of amenities and recreational opportunities of the sea shore, as well as, the convenience and the advantages to be found there for industrial activities. Apart from fall-out from the atmosphere, large amounts of pollutants and waste reach the oceans through the rivers and run-off from the land. The coastal and estuarine waters are increasingly being used for convenient dumping of industrial and sewage wastes. However, because of the enclosed character of some seas, the waste may not be rapidly diluted and dispersed by natural processes. Depending on the nature of the waste and, on transport by currents and winds, it may drift to the coasts of other nations. By drifting out to sea, it may even adversely affect the open sea environment of the plants and animals. The problem is further confounded when the wastes are dumped into an estuary and, the river in its upstream is obstructed by a dam for purported developmental activities and water usage. Such a situation causes the prospect of flush back of the wastes discharged into the estuary to greater distances up the river during periods of tidal ingress, posing serious social, economic and hygienic problems to the populace dwelling on the river banks and, also to the domestic animals. The magnitude and severity of this aspect get magnified especially, when the estuary is situated in a Gulf.

This is the situation that is typically exemplified by the Mahi estuary at the Gulf of Cambay, into which industrial waste is collectively discharged through an effluent channel and, the Mahi river in its upstream has a dam obstructing the flow and minimising the flushing potential of the river. As industrialization is the corner stone of development and, pollution is a problem which is to be accepted as a consequence of the same, mankind should be prepared to meet and combat this problem in various ways so as to minimise the potential hazardous effects. To this end, continuous monitoring and appraisal are a must. The huge Nandesari industrial/petrochemical complex situated on the north western limits of Baroda dispose their complex array of wastes after treatment through a common effluent channel into the Mahi estuary at the Gulf of Cambay. Though the treatment is planned to minimise the quantum and the hazardous nature of the chemical wastes, the basic weakness of human nature and the tendencies of business community can greatly offset the idealized effectiveness of the entire process. Since the effluent channel is of closed conduit type with movable horizontal slabs, running a distance of 56 Km from the Nandesari complex to the Gulf of Cambay, and the populace residing in this entire stretch has developed the practice of pilfering the channel water for irrigative purposes, the effluent water quality and its potential hazardous nature need to be assessed and monitored. Further, the impact of this effluent released into the Mahi estuary on the water quality, at, down and above, the point of discharge need to be also monitored, as there could be deleterious effects on the marine, estuarine and river ecosystems and also may affect the human populace residing along the bank of the river. This is more so because the tidal ingress is reported to extend upto Vasad a distance of about 70 Kms upstream. It is in this context that the water quality assessment of the effluent channel as well as the quality of the water at the point of discharge at Mahi estuary and downstream and up stream of it has been planned and executed in the present study.

METHODOLOGY OF ASSESSMENT

The effluent sample analysis for metal was carried out by collecting samples from 55 points all along the channel (every 01 km), through out the study period. For ease and convenience of handling the data, values of effluent metal content obtained for every 11 km have been clubbed together and mean value calculated. The data is thereby presented under 5 sampling heads all along the channel.

The estuarine water quality assessment has been carried out by collecting samples of water from the estuary at the J-point as well as from 3 Kms downstream and 3 kms upstream of the J.point. The effluent samples have been tested for the metal content, whereas the water samples from estuary were analysised for metal, physico-chemical and biological parameters. Samples were collected and analysied as per the standard methods for examination of water and waste water given in the treatise, prepared and published jointly by the American Public Health Association (APHA), American Water Works Association (AWWA) and the Water Pollution Control Federation (WPCF; 1981).

PHYSICO-CHEMICAL PARAMETERS

TEMPERATURE (^{O}C)

Temperature (^{O}C) and total and dissolved solids were the physical parameters studied. Temperature was measured by using Celsius thermometer. The total solids (TS) was estimated by evaporating to dryness a known quantity of water at a temperature of 103-105 ^{O}C in a silica crucible. The difference in weight between the empty crucible and after evaporating to dryness the sample, is taken as the total content of TS. In another set up, a known quantity of water was filtered through whatman No.42 filter paper and a known quantity of the filtrate was taken in a silica crucible and was evaporated to dryness as above. The difference in weight in this case is taken as total dissolved solids (TDS). The difference between the values of TS and TDS was then taken to represent the amount of suspended solids (SS). The values are represented as mg/l.

pH

The form used to express the intensity of the acidic or alkaline condition of a solution is pH. It is a way of expressing the hydrogen ion concentration or more precisely, the hydrogen-ion activity. In the field of water pollution, it is a factor of significance in chemical coagulation, disinfection of water, water softening, corrosion control and dewatering of sludges. The pH is measured at the site itself by using pH strips as well as with an Orion WTW pH meter. The basic principle of electrometric pH is, determination of the activity of the hydrogen ions by potentiometeric measurements using a glass electrode and reference electrode. In the present study, xerolyte electrodes were used to measure the pH, by dipping electrodes in the waste water sample. The instrument was precalibrated by using pH buffer of 4, 7 and 9.2 pH.

DISSOLVED OXYGEN (DO)

Dissolved oxygen is the oxygen present in water/waste water. It plays a vital role as far as self purification of any water body is concerned. Normally in summer, the DO content in water body is known to be lower than in winter i.e 7-8 ppm as against and 9-12 ppm. Similarly, high dissolved oxygen content is characteristic of fresh water than of sea water. Under no condition the DO should fall below 4 ppm, as it is deleterious for aquatic organisms.

The DO content of natural or waste water depends on the physical, chemical and biochemical activities in the water body. Dissolved oxygen level is measured by the Winklers - azide-modification method and, by the electrometeric method using membrane electrodes. Samples were collected in BOD bottles and fixed at the site itself by adding 2ml each of alkali-azide iodide and manganous sulfate. The bottles were stored at low temperature and were later subjected to titration, using 100 ml. sample with sodium thiosulfate, after adding 2 ml of concentrated sulfuric acid and shaking it well. Starch was used as the external indicator.

BIOCHEMICAL OXYGEN DEMAND (BOD)

The BOD determination is an empirical test in which standardized laboratory procedures are used to determine the relative oxygen requirements of organisms for oxidising organic matter in waste, effluent or polluted water.

The test measures the oxygen required for the biochemical degradation of organic material, unless their oxidation is prevented by inhibitors. The method involves collection of representative samples in BOD bottles and preserving them at low temperature. In the laboratory, samples were diluted according to available COD values (chemical oxygen demand), with dilution water (containing 1 ml each of phosphate buffer, magnesium sulfate and calcium chloride per liter of distilled water along with 2 ml of seed.) Nine dilution bottles involving three dilutions in triplicate and six blank bottles containing only dilution water were taken. Three blank bottles and three diluted sample bottles were fixed with alkali-azide-iodide and manganous sulfate (2ml each) and titrated on the same day for oxygen using sodium thiosulfate with starch as an indicator. Remaining bottles were kept at 20 ^{O}C. in a BOD incubator for 5 days. After 5 days, same procedure was repeated and the depletion in oxygen was calculated and expressed as mg/l.

BOD plays vital role in assessing biodegradable organic loading, and oxygen influx in water body. With this, the biodegradable organic matter is calculated and stream pollution and self purification can be assessed. Higher organic loading of water bodies would demand more oxygen for biodegradation and hence calculation of BOD serves as an index of the amount of organic matter and, an assement of the degree of pollution and of self purification.

CHEMICAL OXYGEN DEMAND (COD)

It is the measure of oxygen equivalent of the content of organic matter in a sample that is susceptible to oxidation by strong chemical oxidant. The sample is preserved with 2 ml of concentrated H_2SO_4.

The dichromate reflux method is used in the present study for measuring COD. For most organic matter, oxidation is 95-100% of the theoretical value. The principle involves boiling (refluxing) the organic matter in strong chromic and sulfuric acids (oxidants) with a known excess of potassium dichromate. After digestion, the remaining unreduced potassium dichromate is titrated with ferrous ammonium sulfate using ferroin as an indicator. The amount of potassium dichromate consumed is determined and the amount of oxidizable organic matter is calculated in terms of oxygen equivalent. Mercuric sulfate (1gm) is added as catalyst to enchance the reaction. The sample mixture with oxidizing agent is refluxed for 2 hrs and the titrations are made in cold condition and the calculated COD value is expressed as mg/l. The COD test helps in finding out the oxidizable organic matter in a short period, thereby helping in treatment facilities. The ratio of COD to BOD gives the feasibility of treatment plant in terms of chemical treatment, biological treatment or both. The COD value reflects the total oxidizable organic loading in the water body.

CHLORIDE (Cl; ARGENTOMETRIC METHOD)

Chlorides occur in all natural water in widely varying concentrations and they increase as the mineral content increases. In the present study, chlorides are analysed by the above mentioned method. A 100ml sample/aliquot made in 100ml is taken and if it is coloured, it is decolourised by using activated charcoal or aluminium hydroxide suspension ($AlOH_3$) and the pH is brought to neutral, and titrated with silver nitrate solution using potassium chromate as an indicator. Titration is continued untill the brick red color is constant. A sample blank is also titrated and chlorides are calculated and expressed as mg/l.

Chloride data helps in assessing scaling in water and their feasibility of disposal on land for irrigation.

SULFATE : (SO_4; TURBIDITY METHOD)

Sulfate is widely distributed in nature and its concentration is of wide significance as it leads to `crown corrosion along with chloride scale in sewers, pipes etc. Under anaerobic condition, it gives a fouling smell of hydrogen sulfide.

A well mixed de-colorised filtered sample is taken (100ml or aliquot made to 100ml) in a 250 ml conical flask into which is added barium chloride and conditioning reagent (2gm and 5ml respectively) and the total volume is made upto 105 ml. The developed turbidity is measured at 420nm immediately. The amount of So_4 is then calculated and expressed as mg/l.

The principle involved is precipitation of sulfate in acidic medium (HCl) with barium chloride so as to form barium sulfate crystals of uniform size. Light absorbance of the $BaSo_4$ suspension is measuered by spectrophotometer at 420nm.

ALKALINITY

The alkalinity of water is a measure of its capacity to neutralize acids. The alkalinity of natural waters is due to the presence of weak acids. Bicarbonates represent the major form of alkalinity. In polluted or anaerobic water, the alkalinity may be due to the salts of weak acids. Ammonia or hydroxides may also contribute to total alkalinity of water.

Alkalinity is measured titrimeterically by titrating with acid (0.02 N H_2SO_4) using phenolphthalein or methyl orange as indicator for end point. The calculated alkalinity value is expressed in terms of mg/l $CaCo_3$.

Alkalinity data helps in chemical coagulation, water softening treatment, corrosion control, and to find out the buffering capacity of waste water and sludges.

HARDNESS - (EDTA TITRIMETRIC METHOD)

Ethylenediamine tetracetic acid and its sodium salts (EDTA) form a chelated soluble complex when added to a solution of metal cations. The divalent ions (Ca++ & Mg++) combine with the dye, Eriochrome-black-T, which is blue in color and imparts wine red color to the samples. Further, on titration with EDTA, Ca++ and Mg++ are complexed and the solution turns from wine red to blue. Here, maintainence of an alkaline pH of 10.0 $\pm$ 0.1 is a must along with addition of 1 ml each of buffer and inhibitor. From EDTA readings, hardness as $CaCO_3$ is calculated and expressed as mg/l. Hardness is an important parameter as far as frothing, and softening of water is concerned.

OIL AND GREASE (SOXHLET EXTRACTION METHOD)

In this, soluble metallic soaps are hydrolyzed by acidification; any oils and solids or viscous grease present are separated from the liquid sample by filtration. After extraction with petroleum ether (PE) or trichloro trifluoro ethane (TCTFE) in soxhlet apparatus, the residue remaining after solvent evaporation is weighed to determine the oil and grease content. By definition, any material recovered is oil and grease and any filterable trichloro trifluoro ethane soluble substances, such as elemental sulphur and certain organic dyes, will be extracted as oil and grease.

500 ml of the sample was acidified (5 ml. Hcl.) and filterd in Bookner funnel with whatman filter paper No. 42 and the paper was transferred to thimble placed in the soxhlet apparatus. The round bottom flask was dried and

preweighed and then 150 ml of petroleum ether/TCTFE was taken into the apparatus and heated at $70^{o}C$ and cycles were adjusted to 20 cycles/hr for 4 hr. Finally, all the PE/TCFE gets collected into the thimble holder. The round bottom flask was weighed again. The difference in weight was calculated and oil and grease was expressed as mg/l.

Oil and grease plays very vital role in water as it primarily increases the organic loading in the effluent, and secondarily it forms a thin film over the water body, thereby disrupting the oxygen influx into the water body making it in due course of time anaerobic. Thirdly, it affects the respiratory activity of the aquatic animals.

PHENOLS (CHLOROFORM EXTRACTION METHOD)

Steam distilled phenol reacts with 4 aminoantipyrine at pH. 7-9 $\pm$ 0.1 in the presence of potassium ferricyanide to form a coloured antipyrine dye. This dye is extracted from aqueous solution with $CHCl_3$ and the absorbance is measured at 460nm.

Sample at site are collected in plastic bottles (500ml) and preserved with $CuSO_4$ (2gm) + H_3PO_4 (2ml). The sample was distilled and the distillate was transferred to separating funnel containing $CHCl_3$, (50 ml), NH_4 buffer (12ml) and 3 ml each of 4-amino antipyrine and potassium ferricyandie. Sample was shaken well and the chloroform layer was collected in dry tubes containing sodium sulfate and after 10 min reading was taken at 460 nm. The phenol content was calculated and expressed as as mg/l. Phenol is toxic for organisms in aquatic systems.

CYANIDE (CN ; TOTAL CYANIDE)

The term refers to all the cyanide as CN in compounds that can be detèrmined as the cyanide ion. Sample is preserved with NaOH at site (pH 10-10.5)

Hydrogen cyanide (HCN) is liberated from an acidified sample containing $MgCl_2$ (20ml) and H_2So_4 1 : 1 (50 ml) by distillation and purging with air. The HCN is collected by passing it through 50 ml of 1N NaOH as scrubbing medium. The cyanide concentration in the scrubbing medium is determined by titrimetric method using autotitrator and the CN content is calculated and expressed as mg/l

Cyanide is very toxic to living systems thus its concentration in effluent should be thoroughly checked so as to sustain life in any water body.

AMMONICAL-NITROGEN (NH_3-N ; TITRIMETRIC METHOD)

Ammonia is measured as ammonical nitrogen in the effluent sample. The sample is preserved with concentrated

H_2SO_4 (2ml). It forms ammonium sulfate. The principle involves the liberation of NH_3-N (at pH 7-10) from $(NH_4)_2SO_4$ during distillation and absorption in boric acid converting it into ammonium borate which is again titrated with H_2SO_4 (0.02N). The colour changes from orignal blue to green and end point is marked with reappearance of blue colour. Free ammonia is very toxic to living systems/animals. In estuarine and fresh water systems, the NH_3-N concentration affects the biota in the water body. NH_3-N was also analysed by electrometric method by using space head technique.

TOTAL KJELDAHL NITROGEN (TKN ; MACRO -KJELDAHL METHOD)

In the presence of H_2SO_4, potassium sulfate (K_2SO_4) and mercuric sulfate ($HgSO_4$) as catalyst, amino nitrogen of many organic materials is converted to ammonium sulfate $[(NH_4)_2,SO_4]$. Free ammonia and organic nitrogen also are converted to $(NH_4)_2SO_4$. During sample digestion, a mercury ammonium complex is formed. After the mercury ammonium complex in the digestate has been decomposed by sodium thiosulfate ($Na_2S_2O_3$), the ammonia is distilled from an alkaline medium and absorbed in boric acid. The ammonia is determined by titration with standard mineral acid (0.02N-H_2SO_4).

Sample was preserved with 2 ml of concentrated H_2SO_4 (pH 2-4) and 100 ml of the sample was taken for digestion with 10 ml of conentrated H_2SO_4 and 3 mg of digestion mixture (K_2SO_4+$HgSO_4$) along with few glass beads and, was boiled till 10 ml residue was left. The sample flasks were cooled and volume was made upto again 100ml (with NH_3-N free distilled water) and was analysed as per the procedure given for NH_3-N. TKN was calculated and expressed as mg/l. Total kjeldahl nitrogen gives an overall account of nitrogen present in complexed form.

BACTERIOLOGY (TOTAL COLIFORM AND FECAL COLIFORM BACTERIA)

Multiple Tube fermentation technique was employed for members of coliform group, expressed as most probable number (MPN).

The coliform group comprises all aerobic and facultative anaerobic gram negative, non-spore forming rod shaped bacteria that ferment lactose with gas formation within 48 hrs at $35^{o}C$.

Sample was collected in sterilized glass bottle and autoclaved for 15min at 15 lbs). All the glassware and media were autoclaved/sterilized. Fifteen tubes containing McKonky's broth were taken for each sample of which the first 5 tubes were having medium of double strength and others of single strength. The tubes were inoculated with 10 ml, 1ml or 0.1 ml of the sample in aseptic condition and were incubated for 24-48 hrs for gas formation at 35 $\pm$ 2^{O}C. After 48 hr, all the positive tubes showing gas formation in the Durham's tube were inoculated into the brilliant green lactose broth (BGLB) the second media with a platinum loop and were incubated for 48 hrs for gas formation. From this, all the positive results were considered and total coliform were found out from the table.

Positive tubes from total coliform test were taken and inoculated into enterococci (EC) broth and incubated at 44.5 $\pm$ 2^{O}C for 48 hrs and positive results were noted and, from the table counts were recorded. All the results were expressed as fecal coliform, MPN/100ml.
The coliform count is important in assessing the quality of water.

METALS

All samples containing metals were collected in plastic bottles and preserved with 2 ml of Conc HNO_3 except for Chromium (Cr) and Mecury(Hg). All the metals were brought into soluble state with HNO_3 and H_2SO_4 (2 ml each) and 100ml of the sample was taken and digested on hot plate except, the sample for mercury and chromium which were just warmed and taken back for analysis. All other metal containing flasks were subjected for digestion till the sample volume was reduced to 10ml. The volume was readjusted to 100ml and was filtered with whatman filter paper No-40 and aspirated into an Atomic Absorption Spectrophotometer (AAS).

For Calibration of standards, BDH-chemicals were used for all metals. Mercury (Hg) analysis was done by using cold vapour generation hydride system in AAS and results were expressed in mg/l. Metals play very important role in environmental analysis as they form the non-degradable mass in a system, thereby accumulating in the body, and impairing functional integrity of any system.

RESULTS

The metal content of effluent channel water as mean, under 5 sampling héads (mean of 11 points each) is shown in table 1.

TEMPERTURE (^{0}C)

In general, higher temperatures were recorded between April and October with a maximum of 32 -34^{o}C being recorded during April and June. The minimum temperature was consistently during January. The monthly variations in

0▲

TABLE 1 : MEAN HEAVY METAL CONTENT IN THE EFFLUENT ALONG THE CHANNEL (1ppm)

	METALS							
NO.	CHROMIUM	LEAD	NICKEL	COPPER	ZINC	CADMIUM	MERCURY	IRON
I	0.066	0.230	0.023	0.090	0.124	0.013	0.005	0.154
II	0.107	0.233	0.101	0.117	0.179	0.017	0.010	0.437
III	0.037	0.141	0.022	0.088	0.097	0.052	0.001	0.092
IV	0.027	0.086	0.013	0.087	0.034	0.075	0.003	0.068
V	0.063	0.095	0.041	0.110	0.044	0.047	0.001	1.680

temperature over the period of 3 years are shown in table 2 and (Figs- 1 and 2) . Though there were occasional variation in temperature ranging between 1 to 2^{O} C at the 3 points of study, in general, temperature tended to remain the same at the three points.

pH

The monthly variation in pH at the 3 points are shown in table 3. The pH has tended to decrease significantly from '91 to '93 at all the 3 points. The minimum pH value came down form 6.9 in 1991 to 6.4 in 1993. The average pH changed from 7.5 in 1991 to 7.3 in 1992 and 7.0 in 1993. These changes in pH at the J-point were reflected in the pH at upstream and downstream. In many months, up stream pH values tended to be even lower than those recorded at the J-point. The changes in average pH value and percentage alterations over the three year period are shown in figures 1 and 2.

TOTAL SOLIDS (TS)

Maximum TS has been found in the downstream area followed by the J-point and up stream. Both at the J-point and upstream, T.S. recorded significant increase from 1991 to 1993 amounting to 17.39% and 73.25% respectively. The monthly recording of TS content in the downstream area showed greater fluctuation while, there was consistent tendency for the

TABLE 2 : MONTHLY VARIATIONS IN TEMPERATURE (C) AND, RANGE,MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	25	25	25	24	23	24	23	24	23	22	24	24
FEB	27	26	26	26	24	24	24	24	28	27	24	25
MAR	27	26	26	26	26	25	25	26	31	30	24	25
APR	32	32	31	31	31	32	31	31	31	30	33	31
MAY	33	32	32	32	33	32	33	32	32	31	32	33
JUN	33	30	31	33	34	31	33	33	32	31	32	33
JUL	30	30	30	31	31	31	32	33	32	30	31	30
AUG	32	32	33	33	31	31	31	32	32	30	33	32
SEP	32	32	32	32	31	31	30	29	30	30	30	31
OCT	32	32	31	31	28	30	28	27	30	30	29	32
NOV	29	29	29	29	28	28	27	26	28	27	28	29
DEC	24	27	26	26	25	26	24	24	25	26	26	25
MEAN	29.7	29.4	29.3	29.5	28.8	28.8	28.4	28.4	29.5	28.7	28.8	29.2
MIN	24	25	25	24	23	24	24	24	23	22	24	24
MAX	33	32	33	33	34	32	33	33	32	31	33	33
PERCENTAGE CHANGE FROM 1991-1993									-0.89	-2.18	-1.6	-1.12

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J'' POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J'' POINT

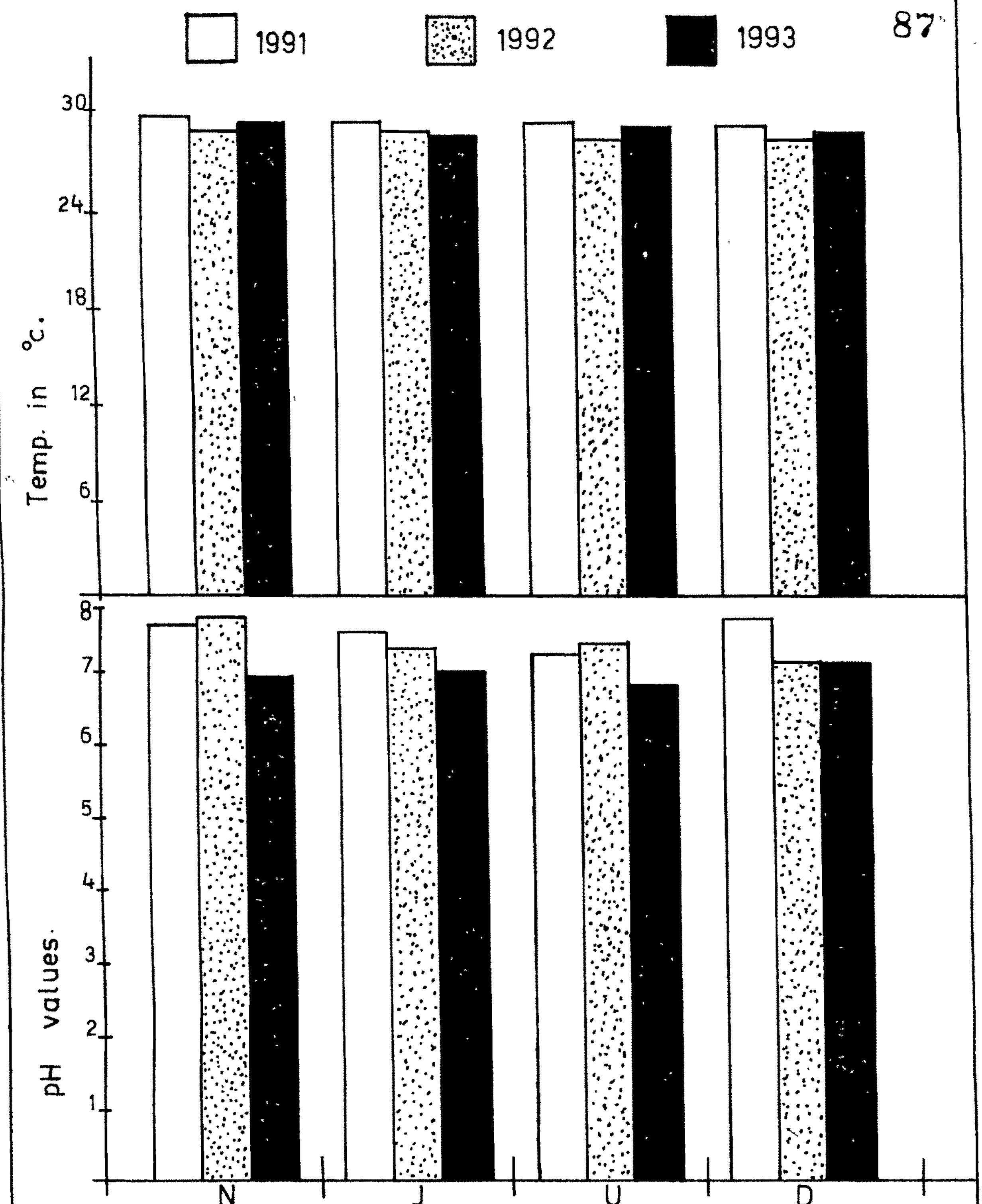


Fig.1 - Average temperature and pH between 1991-1993 at the Mahi estuary.
N-Nahar, J-J point, U-Upstream, D-Downstream.

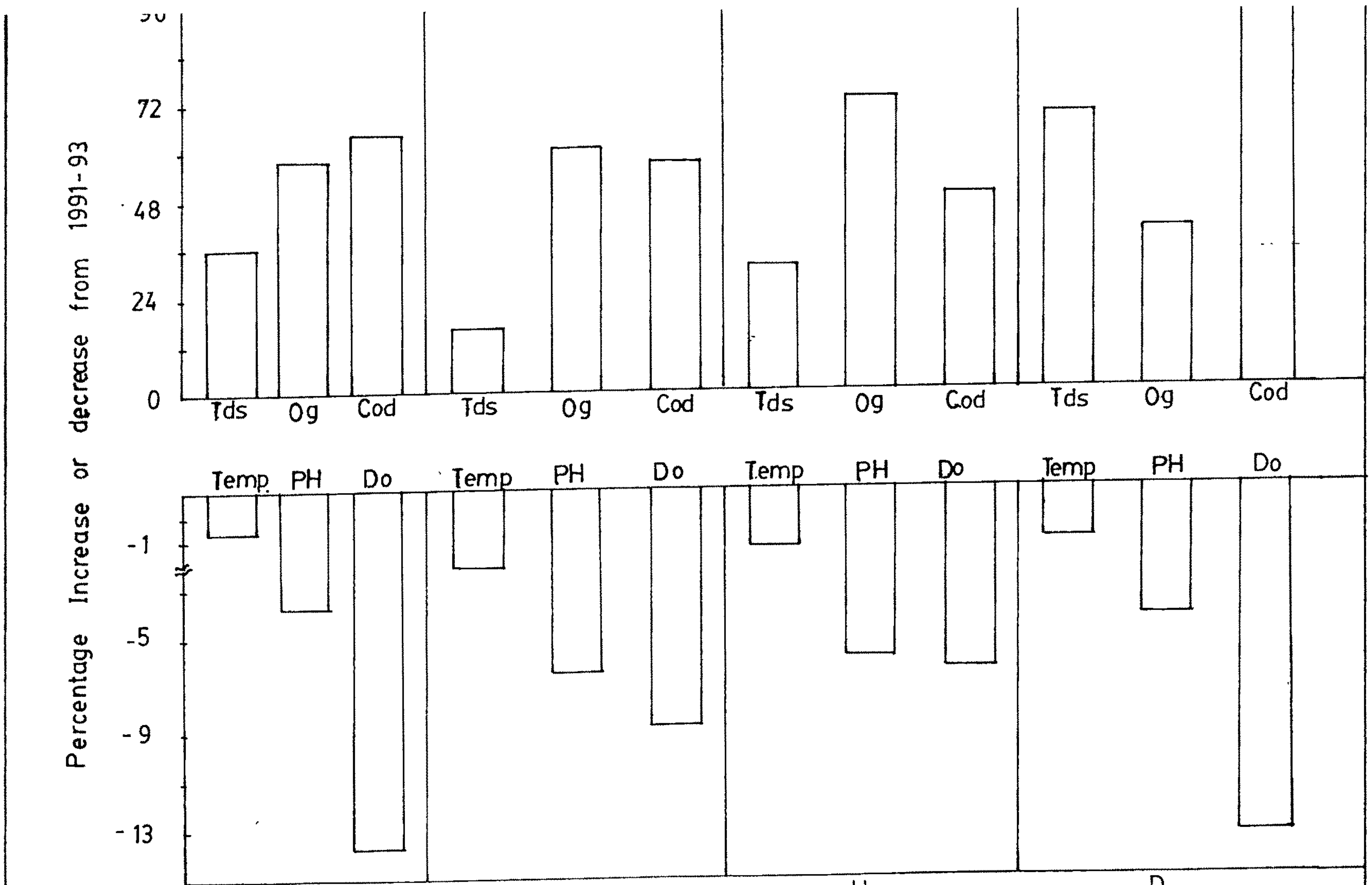


Fig. 2 Percentage alterations in some physico chemical parameters at Mahi estuary from 1991-1993

N=Nahar, J='J' Point, U=Upstream, D=Downstream

TABLE 3 : MONTHLY VARIATIONS IN pH AND, RANGE, MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	7.5	7.5	8.0	7.0	8.1	7.8	7.8	7.9	8.3	7.9	8.0	7.9
FEB	7.6	7.9	8.1	7.7	7.9	7.5	7.2	7.8	7.0	7.6	7.2	7.7
MAR	6.8	7.7	7.8	6.7	7.6	7.1	6.9	7.2	6.9	7.2	7.8	6.7
APR	7.7	6.9	6.9	7.5	8.0	7.2	7.0	7.2	7.2	6.5	6.2	7.3
MAY	7.8	7.5	8.0	7.0	7.4	7.2	7.3	7.0	7.3	7.1	7.1	6.9
JUN	7.6	7.2	7.5	7.0	7.4	7.1	7.3	6.9	7.6	7.4	7.4	6.0
JUL	7.6	7.2	7.7	7.2	7.2	6.9	7.2	7.0	7.6	7.0	7.5	7.3
AUG	7.8	7.6	7.9	7.3	8.1	6.9	7.7	7.0	7.9	7.0	7.0	7.0
SEP	7.9	7.6	7.9	7.9	7.2	7.0	7.2	6.9	7.7	7.2	6.7	7.7
OCT	7.8	7.6	7.8	7.0	8.2	7.4	4.3	7.5	4.8	6.4	7.0	5.9
NOV	7.6	7.6	7.7	7.5	8.1	7.7	7.7	7.9	4.3	6.4	6.8	5.9
DEC	7.6	7.7	8.1	7.3	8.0	7.8	7.7	7.9	6.8	6.4	7.0	6.1
MEAN	7.6	7.5	7.8	7.3	7.8	7.3	7.1	7.4	7.0	7.0	7.1	6.9
MIN	6.8	6.9	6.9	6.7	7.2	6.9	6.9	6.9	4.4	6.4	6.7	6.7
MAX	7.9	7.7	7.8	7.9	8.2	7.8	7.7	7.9	8.3	7.9	7.9	7.7
PERCENTAGE CHANGE FROM 1991-1993									-3.8	-6.7	-6.0	-4.4

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J'' POINT

J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J'' POINT

value to be lower during the monsoon months. These changes in the TS. content at the three points over the three year period of study are given in table 4 & figures 3 and 4.

TOTAL DISSOLVED SOLIDS (TDS)

The content of TDS at the J-point, upstream and downstream form 1991-93 is shown in table 5. TDS was also higher at downstream compared to the J-point and upstream. Though the TDS value at downstream tended to remain more or less constant, it increased significantly over the 3 years period at the J-point and upstream. The increase was to the tune of 23% and 85% respectively. (Figs- 2 and 3)

SUSPENDED SOLIDS (SS)

Value of SS, recorded for the 3 year period at the 3 points of study are shown in table 6 and figures 4 and 5. In general, SS recorded a consistent and significant increase at all the three points from 1991 to 1993. The increase at these points was of lesser magnitude as compared to TDS and was to the tune of 78.3% and 24.52% respectively. Both the minimal and maximal values recorded during a year increased from 1991 to 1993.

DISSOLVED OXYGEN (DO)

The DO content at the J-Point, downstream and upstream,

TABLE 4 : MONTHLY VARIATIONS IN TOTAL SOLIDS (TS, mg/l) AND, RANGE,MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	1980	15605	31019	130	1656	12789	25448	132	1703	15162	30192	192
FEB	1650	15597	30999	175	1690	12739	25304	180	1709	16033	31886	196
MAR	1956	17216	34200	210	1960	1574	29938	220	1839	17057	34114	233
APR	2000	15114	29861	127	2080	14563	29000	168	1832	15584	31000	167
MAY	1832	10915	21632	133	2709	12456	24780	248	1788	15574	30900	198
JUN	1828	16305	32300	160	2675	16219	32278	270	2032	15591	30913	310
JUL	1600	2164	4121	110	1578	1935	3167	118	2113	2053	3989	207
AUG	1582	2758	5150	130	1809	2250	4300	180	3113	2373	4567	307
SEP	1448	2897	5791	161	1697	1461	2762	174	5210	1691	3209	403
OCT	1626	3973	7608	169	1709	5117	10062	173	2069	5591	11009	339
NOV	1838	4149	8011	140	2057	14136	28132	167	2563	14770	29373	287
DEC	1610	2919	5532	170	1981	7075	13980	183	2010	7200	14217	307
MEAN	1745.8	9134.3	18018.7	151.3	1966.8	8526.2	19095.9	184.4	2331.8	10723.3	21280.8	262.2
MIN	1448	2164	4121	110	1578	1461	2762	118	1703	1691	3209	167
MAX	2000	17216	34200	210	2709	16219	32278	270	5210	17057	34114	403
PERCENTAGE CHANGE FROM 1991-1993									+33.5	+17.5	+34.8	+72.9

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J'' POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J'' POINT

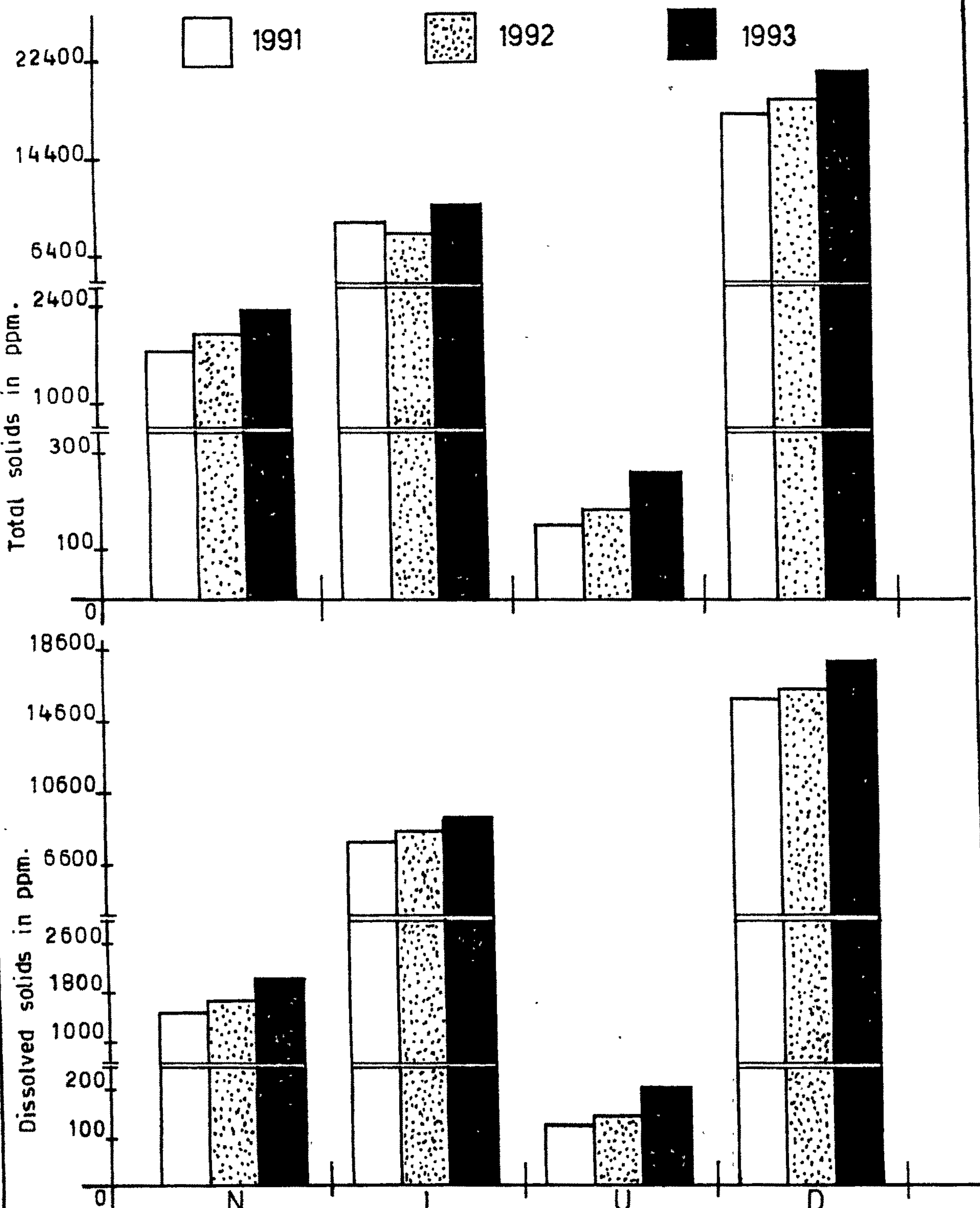


Fig. 3 - Average content of total solids and dissolved solids between 1991-1993 at the Mahi estuary.
N-Nahar, J-J point, U-Upstream, D-Downstream.

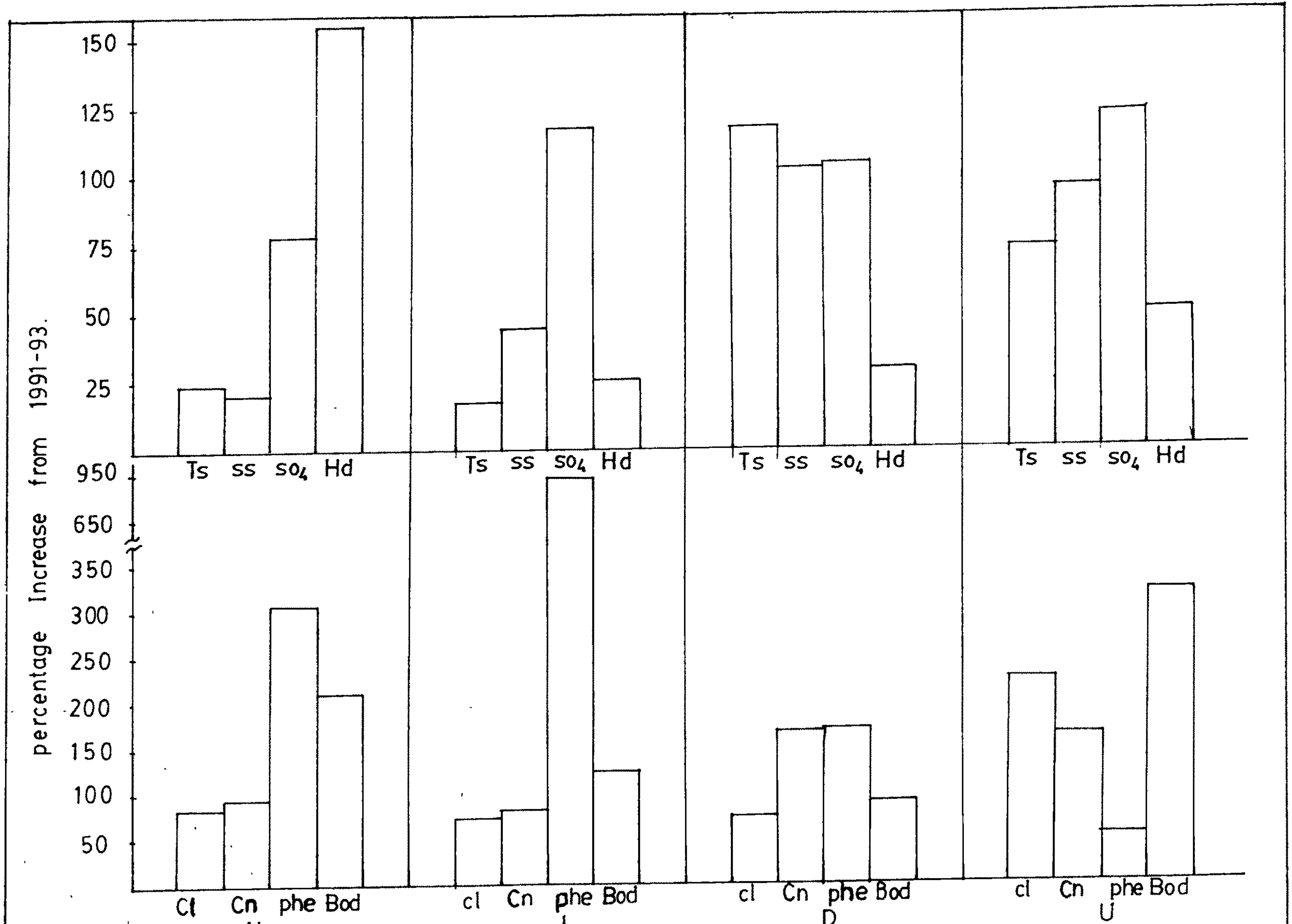


Fig.4 Percentage Increase in some Physico chemical parameters at Mahi estuary from 1991-93.

TABLE 5 : MONTHLY VARIATIONS IN TOTAL DISSOLVED SOLIDS (TDS, mg/l) AND, RANGE, MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	1780	15205	30169	108	1436	12289	23923	96	1503	14550	28692	147
FEB	1467	15222	30000	149	1454	12214	23804	135	1455	15444	30318	148
MAR	1742	16836	33513	185	1709	14539	28197	181	1573	16508	32445	189
APR	1788	14514	28973	105	1859	14023	27644	123	1543	14973	29110	128
MAY	1651	10535	20700	106	2463	11920	23558	212	1555	14998	28901	158
JUN	1603	15740	31511	128	2386	15690	30379	220	1777	14940	29124	261
JUL	1275	1632	3110	69	1268	1335	1578	71	1914	1387	1400	151
AUG	1195	2236	4163	98	1478	1689	2511	132	2926	1695	1898	238
SEP	1127	2297	5113	135	1410	862	1775	129	4945	1106	753	354
OCT	1514	3673	6093	150	1498	4562	9063	136	1403	5042	10223	286
NOV	1627	3819	7122	125	1848	13669	26643	134	2405	14171	27784	239
DEC	1519	2619	4453	155	1684	6674	12176	149	1769	6413	11921	259
MEAN	******	8694.0	17076.7	126.1	1707.8	9122.2	17604.3	*****	2064.0	10102.3	19380.8	213.2
MIN	1127	1632	3110	69	1268	862	1578	71	1403	1106	753	128
MAX	1788	16836	33513	185	2463	15690	30379	220	4954	16508	32445	354
PERCENTAGE CHANGE FROM 1991-1993									+35.5	+16.1	+30.6	+68.7

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF "J"POINT
J - AT "J" POINT (AFTER CONFLUE
U - UP STREAM OF "J"POINT

TABLE 6 : MONTHLY VARIATIONS IN SUSPENDED SOLIDS (SS, mg/l) AND, RANGE,MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	200	400	850	22	220	500	1525	36	200	612	1500	45
FEB	183	375	999	26	236	525	1500	45	254	589	1568	48
MAR	214	380	687	25	251	535	1741	39	266	549	1669	44
APR	212	500	888	22	221	540	1356	45	289	611	1890	39
MAY	189	380	932	27	246	536	1222	36	233	576	1999	40
JUN	225	565	789	32	289	529	1899	50	255	651	1789	49
JUL	325	532	1011	41	310	600	1589	47	199	666	2589	56
AUG	387	522	987	32	331	561	1789	48	187	678	2669	69
SEP	321	600	678	26	287	599	987	45	256	585	2456	49
OCT	112	300	1515	19	211	555	999	37	666	549	786	53
NOV	211	330	889	15	209	467	1489	33	158	599	1589	48
DEC	91	300	1079	15	297	401	1804	34	241	787	2296	48
MEAN	222.5	432.0	942.0	25.2	259.0	529.0	1491.7	41.3	267.0	621.0	1900.0	49.0
MIN	91	300	678	15	209	401	987	33	158	549	786	39
MAX	387	600	1515	41	331	600	1899	50	666	787	2669	69
PERCENTAGE CHANGE FROM 1991-1993									+20.0	+43.7	+101.7	+94.7

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J'' POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J'' POINT

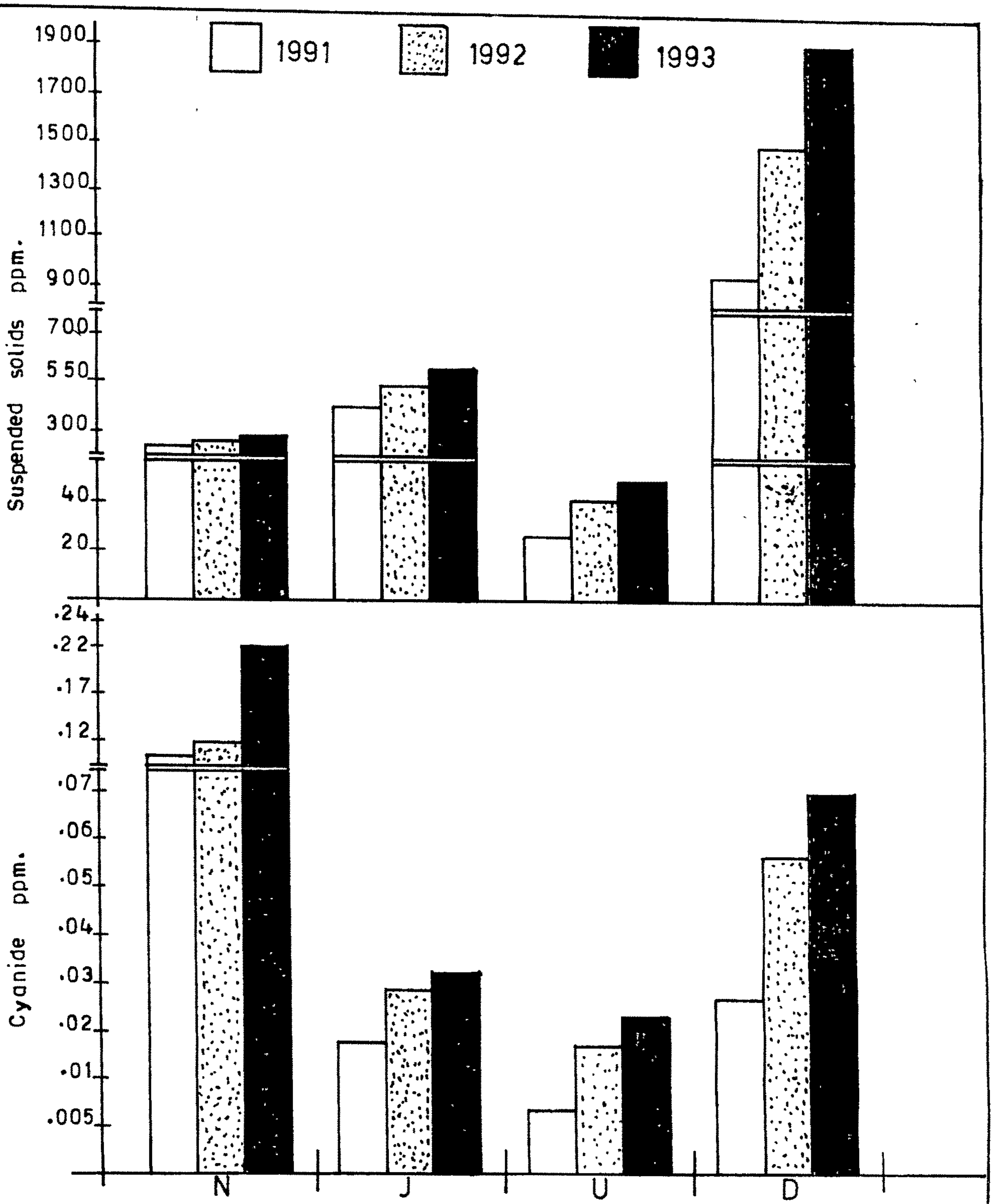


Fig. 5 – Average values of suspended solids and cyanide from 1991–1993 at Mahi estuary.

N - Nahar, J - J point, U–Upstream, D - Downstream.

from 1991 to 1993 is shown in Table No. 7 and figures 2 and 6. The DO content at downstream tended to remain at 7.0 mg/l during the 3 year period of study. But the DO value decreased from 7.1 mg/l to 6.16 mg/l from 1991 to 1993 at up stream. At the same time, the DO value at the J-Point decreased to 7.18 mg/l or less. Both the highest and lowest DO values recorded for the 3 years at the J-point tended to decrease over the 3 years.

CHEMICAL OXYGEN DEMAND (COD)

The average yearly COD increased from 249 mg/l to 373.25 mg/l at downstream, 139 mg/l to 217 mg/l at the J-point and from 31.1 mg/l to 62.2 mg/l at the upstream, an increase of 50%, 56% and 100% respectively at downstream at J-point and at upstream respectively. The data of COD is recorded in table 8 and figures 2 and 7.

BIOLOGICAL OXYGEN DEMAND (BOD)

The BOD values recorded for the 3 year period as shown in table 9 and figures 2 and 7 reveal significant increase at all the 3 points. Whereas the annual average BOD value increased from 23.89 mg/l to 53.2 mg/l at the J-point, it increased from 41.29 mg/l to 78.0 mg/l at the downstream and from 6.5 mg/l to 28.4 mg/l at the upstream. The overall increase was 122.68%, 89% and 337% respectively at the 3 points.

TABLE 7 : MONTHLY VARIATIONS IN DISSOLVED OXYGEN (DO, mg/l) AND, RANGE, MEAN AND THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	6.0	7.9	8.2	7.7	5.0	7.5	7.9	6.9	4.6	7.3	7.5	7.8
FEB	6.9	7.9	9.1	7.7	4.0	7.8	7.2	7.0	4.8	6.7	5.0	7.6
MAR	5.4	5.9	8.2	7.7	4.0	6.0	6.8	7.0	4.5	7.0	6.8	7.0
APR	4.8	7.5	7.3	6.9	4.2	7.3	7.3	6.5	4.8	6.2	3.9	6.8
MAY	6.5	7.5	6.6	6.9	6.2	7.5	6.5	6.9	5.1	6.0	7.1	6.7
JUN	6.0	7.5	6.2	6.9	6.3	7.7	7.1	6.7	5.1	6.4	7.0	6.7
JUL	6.0	7.5	6.0	6.9	4.2	7.8	7.0	7.0	5.0	6.7	6.9	6.9
AUG	6.7	6.7	6.8	7.0	6.8	6.5	7.0	7.0	5.0	6.5	6.8	6.2
SEP	6.4	6.7	4.3	6.9	6.0	6.8	6.9	6.9	5.0	6.5	7.0	5.9
OCT	5.2	7.5	6.7	6.9	6.3	7.0	7.0	7.0	4.3	6.7	6.2	4.0
NOV	2.5	6.5	6.8	7.0	5.9	6.5	6.9	6.9	4.3	6.0	7.0	4.3
DEC	5.3	6.5	6.0	7.2	6.3	6.3	7.0	7.9	4.3	6.0	8.0	4.1
MEAN	5.6	7.1	6.9	7.1	5.4	7.1	7.1	7.0	4.7	6.5	6.6	6.2
MIN	4.0	5.9	4.3	6.9	4.0	6.0	4.9	6.0	3.2	6.0	6.5	4.0
MAX	7.9	7.0	8.2	7.7	6.8	7.8	8.0	7.9	6.3	7.3	7.9	7.8
PERCENTAGE CHANGE FROM 1991-1993									-13.7	-8.8	-6.5	-13.2

* N - NAHAR (BEFORE CONFLUENCE) J - AT ''J'' POINT (AFTER CONFLUENCE)
D - DOWN STREAM OF ''J'' POINT U - UP STREAM OF ''J'' POINT

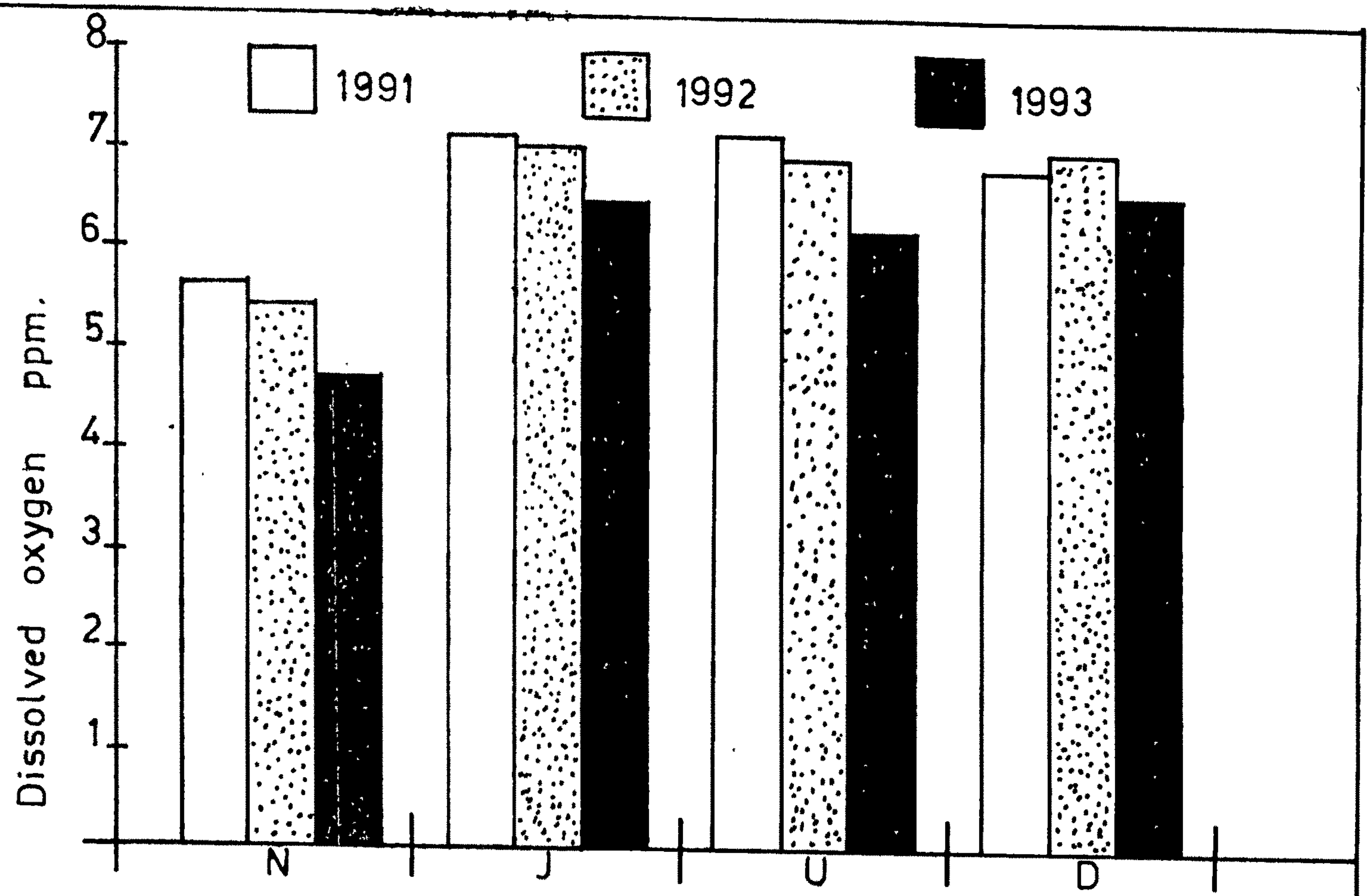


Fig. 6 - Average dissolved oxygen content from 1991-1993 at the Mahi estuary.

N-Nahar, J-J point, U-Upstream, D-Downstream.

TABLE 8 : MONTHLY VARIATIONS IN CHEMICAL OXYGEN DEMAND (COD, mg/1) AND, RANGE, MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	204	160	368	37	400	107	594	22	167	129	233	25
FEB	371	171.6	174	33	232	98	440	29	100	109	310	32
MAR	195	100	149	39	228	127	384	32	192	147	400	29
APR	397	98	257	30	400	162	300	37	409	98.6	260	22
MAY	132	150	303	29	200	121	267	40	500	85.04	366	29
JUN	127	133	105	29	228	153	303	40	397	187	432	32
JUL	400	147	201	29	607	167	353	47	563	193	408	80
AUG	170	102	200	29	403	147	309	32	407	207	451	110
SEP	700	98	80	30	403	132	79	37	533	333	396	233
OCT	327	102	68	29	457	289	611	40	437	461	309	42
NOV	343	275	914	30	531	462	98	37	409	286	437	51
DEC	102	142	94	30	309	288	309	47	608	373	477	41
MEAN	289.0	139.9	242.8	31.2	366.5	187.8	337.3	36.7	393.5	217.4	373.3	60.5
MIN	102	98	68	29	200	98	79	22	100	85.04	233	25
MAX	700	275	914	39	607	462	594	47	608	461	477	233
PERCENTAGE CHANGE FROM 1991-1993									+63.8	+56.0	+47.6	+100

* N - NAHAR (BEFORE CONFLUENCE) J - AT ''J'' POINT (AFTER CONFLUENCE)

D - DOWN STREAM OF ''J'' POINT U - UP STREAM OF ''J'' POINT

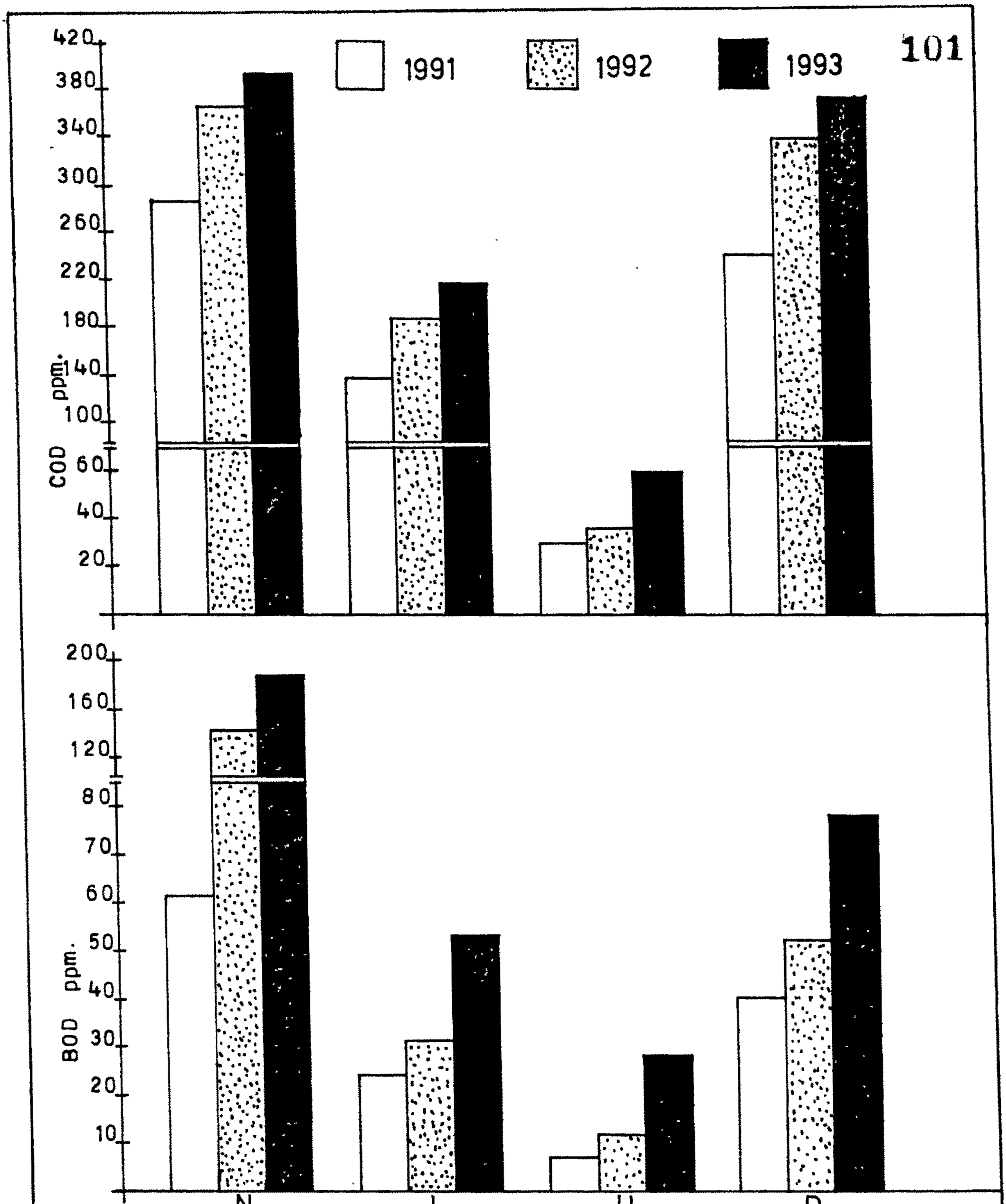


Fig. 7 - Average BOD and COD values from 1991-1993 at the Mahi estuary.
N- Nahar, J - J point, U - Upstream, D - Downstream.

TABLE 9 : MONTHLY VARIATIONS IN BIOCHEMICAL OXYGEN DEMAND (BOD, mg/l) AND, RANGE, MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	40	37	5	4	88	28.91	4.5	6	98	61	66	11
FEB	37	22	6.96	4	50	30.3	4.6	6	111	62	87	19
MAR	51	24	5.2	7	101	45.1	5	7	100	57	33	17
APR	50	23	40	7	150	27.3	37	11	140	30.4	80	12
MAY	40	27	4.9	4	179	33.25	42	12	140	30	32	13
JUN	47	29	2.7	7	130	27	42	12	160	62	37	19
JUL	60	13.32	16	7	110	33	97	18	139	47	149	42
AUG	50	19	3	7	180	29	96	11	133	50	90	60
SEP	53	22	14	6	180	40	39	12	110	39	63	98
OCT	67	19.25	6.4	7	210	37	35	11	254	53	97	13
NOV	191	20.11	386	9	210	29.17	187	11	400	78	101	20
DEC	47	31	5.4	9	139	19.89	37	17	473	69	101	17
MEAN	61.1	23.9	41.3	6.5	143.9	31.7	52.2	11.2	188.2	53.2	78.0	28.4
MIN	37	13.32	3	4	50	19.89	4.5	6	48	30	32	11
MAX	191	37	386	9	210	45.1	187	18	217	78	149	98
PERCENTAGE CHANGE FROM 1991-1993									+208.0	+122.6	+88.9	+337.0

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J''POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J''POINT

CHLORIDE (Cl^-)

The Cl^- content was the highest at downstream and it tended to fluctuate significantly during the 3 years. However, the average Cl^- content at the J-point and up stream recorded a consistent and significant increase. Whereas the Cl^- content at the J-point increased from 31.31 mg/l to 54.44 mg/l, it increased from 30.41 mg/l to 97.41 mg/l at the upstream. The overall increase at the 2 points being 74% and 221% respectively. These changes in Cl^- content are shown in table 10 and figures 4 and 8.

SULPHATE (SO_4)

The So_4 content at the 3 points from 1991 to 93 is shown in table 11 and figures 4 and 8. Overall, the So_4 content increased form 1991 to 1993 at all the three points. The increase in So_4 content at the 3 points was to the extent of 117% at the J-point, 122% at upstream and 104% at downstream.

ALKALINITY

The alkalinity as shown in table 12 and figures 9 and 10 shows reduction over the three year period. Whereas the alkalinity decreased from 152.29 mg/l to 89.49 mg/l at the

TABLE 10 : MONTHLY VARIATIONS IN CHLORIDE (Cl, mg/l) AND, RANGE, MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	950	2217	11000	38	524	7313	15900	36	600	10031	15750	95
FEB	470	5356	2936	30	510	691	8800	20	520	9039.42	16700	99
MAR	560	6219	13032	37	600	6798	1600	7	430	10353.5	1600	88
APR	53	6319	9600	29	60	8031	17000	33	620	9481	18200	79
MAY	510	5197	11300	30	72	8457	12000	3	282	5339	19300	108
JUN	480	8329	8632	30	57	7210	16000	37	650	6739	7000	123
JUL	511	929	899	17	603	67	899	57	403	483	967	152
AUG	400	217	3117	20	709	359	650	47	2511	882	1463	110
SEP	28	89	3916	30	537	430	970	43	3316	132	1372	87
OCT	370	236	3117	39	483	2867	5100	37	783	138	6130	90
NOV	448	410	4113	32	800	4099	3200	60	579	8.387	10000	88
DEC	460	990.4	31110	33	807	3994.24	6400	57	730	3022	6502	51
MEAN	516.3	3130.7	6231.0	30.4	625.9	4725.5	9409.9	40.6	952.0	5443.9	10790.3	97.5
MIN	28	2197	899	17	57	3994.24	650	17	282	4039.42	967	43
MAX	950	3410	13032	39	807	5430	17000	60	3316	6739	19300	219
PERCENTAGE CHANGE FROM 1991-1993									+84.3	+73.8	+73.1	+220.6

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J'' POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J'' POINT

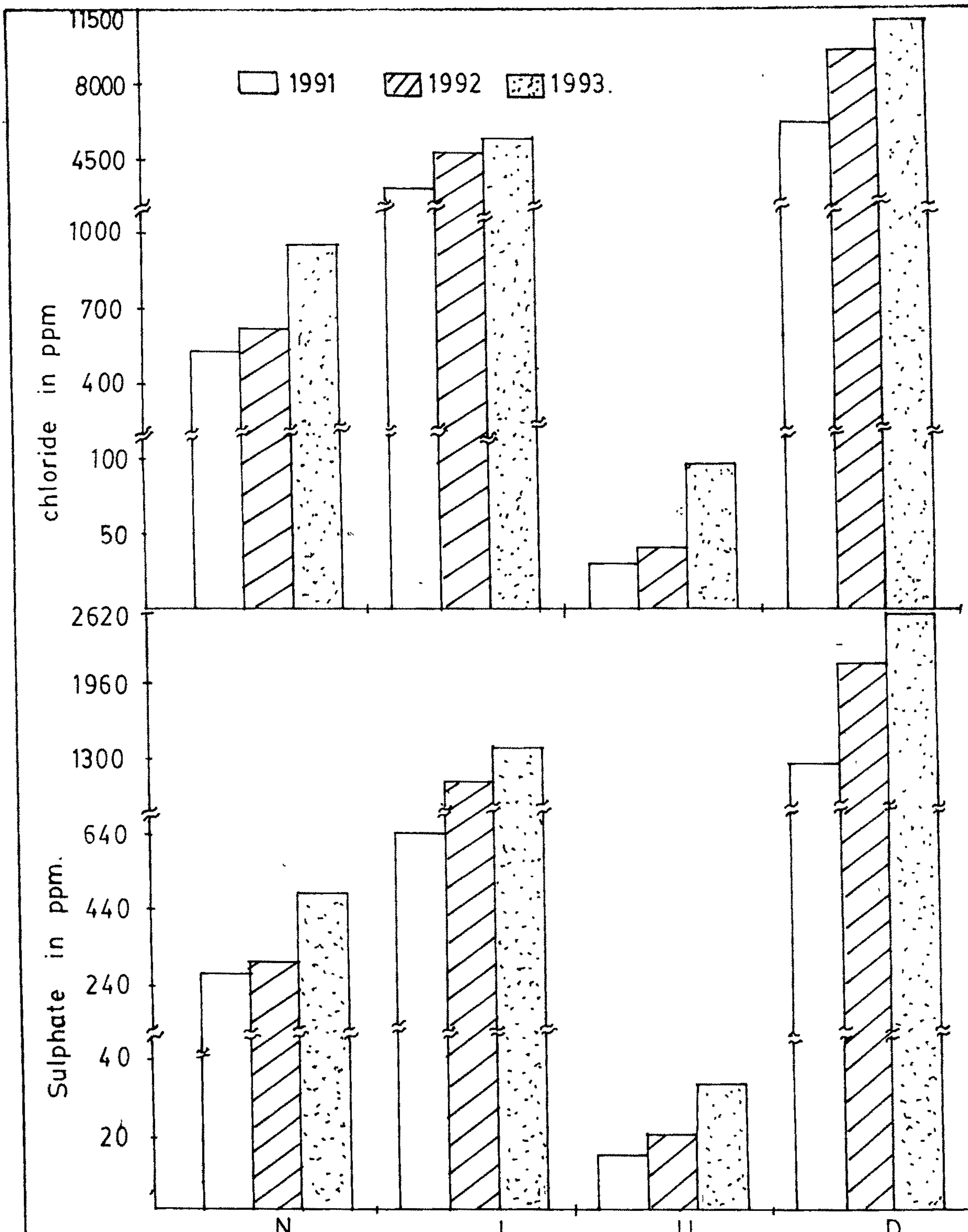


Fig 8 Average Content. of sulphate and Chloride from 1991-1993 at the Mahi estuary.

[N – NAHAR] [J – J POINT] [U – UPSTREAM] [D – DOWN STREAM]

TABLE 11 : MONTHLY VARIATIONS IN SULFATE (SO4, mg/l) AND, RANGE,MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	350	699	1625	17	367	1283	2160	20	447	2139	7000	28
FEB	618	809.65	1350	10	378	1177	2052	17	399	2087	1872	42
MAR	600	845	2233	11	486	2621	237	20	672	2127	9000	42
APR	330	1273	960	18	23	1483	990	21	513	2226	3000	24
MAY	330	599	2450	17	32	1200	969	27	133	995.92	8000	27
JUN	430	327	1785	17	34	786.11	980	16	310	1298	792	47
JUL	19	285	169	9	207	102	302	11	347	467	308	12
AUG	200	95	432	11	63	898	600	22	298	517	319	60
SEP	217	688	248	10	246	412.33	522	17	600	683	313	60
OCT	45	703.41	810	19	197	693	820	19	917	1524	134	27
NOV	64	688.1	2268	20	1000	1263	11011	19	600	1207	76	17
DEC	69	673	864	23	503	1178	5314	27	587	1400	124	18
MEAN	272.667	640.43	1266.167	15.167	294.66667	1091.37	2163.083	19.667	485.25	1389.243	2578.167	33.667
MIN	19	285	169	9	23	612.33	237	11	133	995.92	76	12
MAX	618	809.65	2450	23	1000	1483	11011	27	917	1524	9000	60
PEPCENTAGE CHANGE FROM 1991-1993									+77.9	+116.9	+103.6	+122.0

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J''POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J''POINT

TABLE 12 : MONTHLY VARIATIONS IN ALKALINITY (mg/l) AND, RANGE, MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	340	173	230	110	112	193	164	87	92	88	124	69
FEB	377	165	332	140	164	164	180	73	40	97	136	60
MAR	319	166	333	73	167	175	152	72	118	99	156	67
APR	124	189	280	119	138	189	207	127	178	109	197	68
MAY	107	137	432	98	164	188	209	130	160	69.22	171	70
JUN	128	120	602	87	100	107	302	132	154	98	128	80
JUL	78	119	69	47	178	101	167	50	68	67	150	69
AUG	98	133	97	55	148	111	109	60	66	101	208	77
SEP	104	149	71	65	60	121	97	56	98	83	148	88
OCT	94	129	46	68	20	107	300	70	104	97	147	66
NOV	78	178	93	60	88	140.5	437	62	98	101	148	81
DEC	158	169.84	64	73	168	123.46	121	87	100	64.66	332	74
MEAN	167.1	152.3	220.8	82.9	125.6	143.3	203.8	83.8	106.3	89.5	170.4	72.4
MIN	78	119	46	47	20	101	97	50	40	64.66	124	38
MAX	377	189	602	140	178	189	437	132	178	109	332	108
PERCENTAGE CHANGE FROM 1991-1993									-36.5	-41.2	-22.7	-12.7

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J'' POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J'' POINT

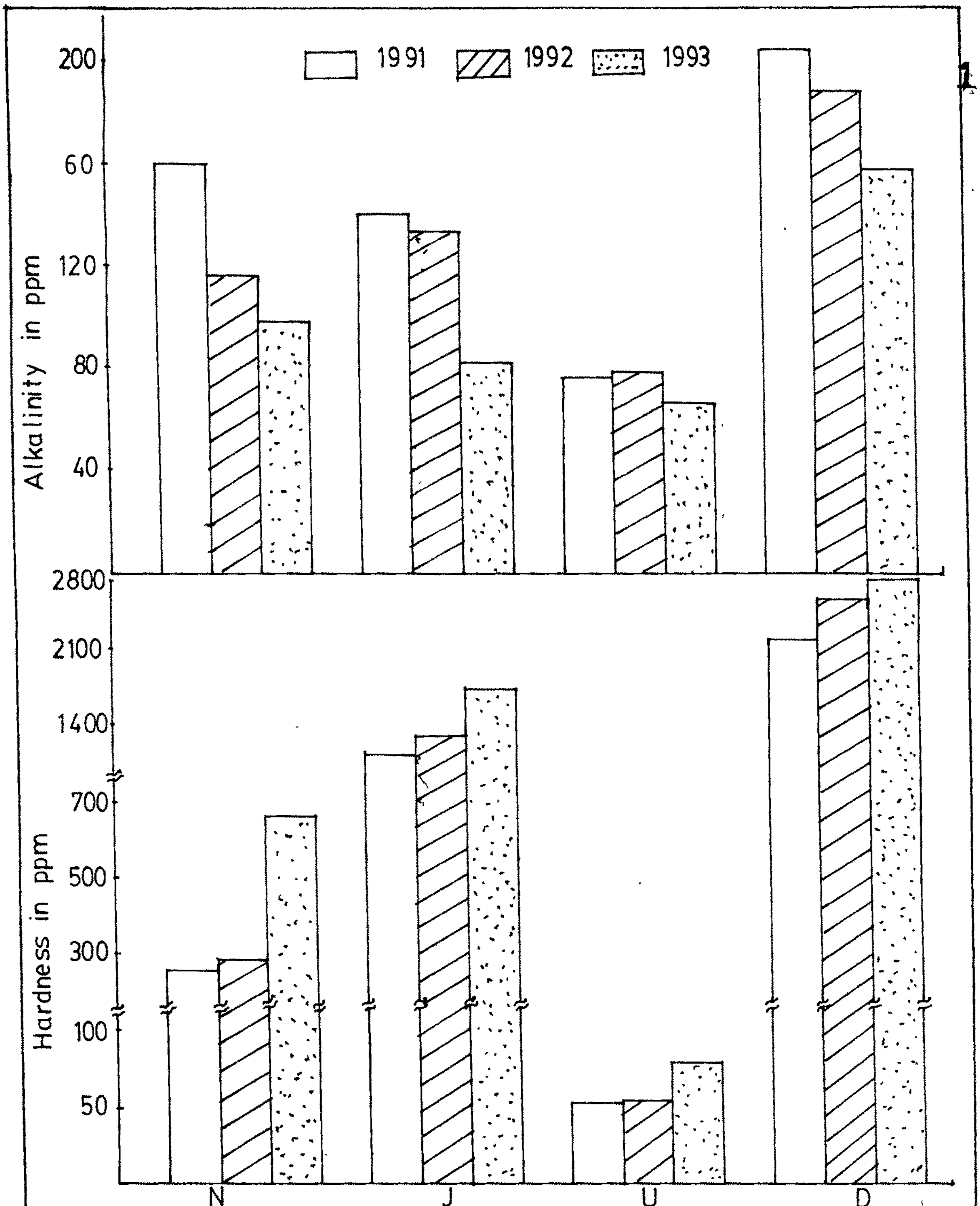


Fig.9 Average alkalinity and hardness from 1991-93 at the Mahi estuary.

N = Nahar, J='J' point, U=Upstream, D=Downstream.

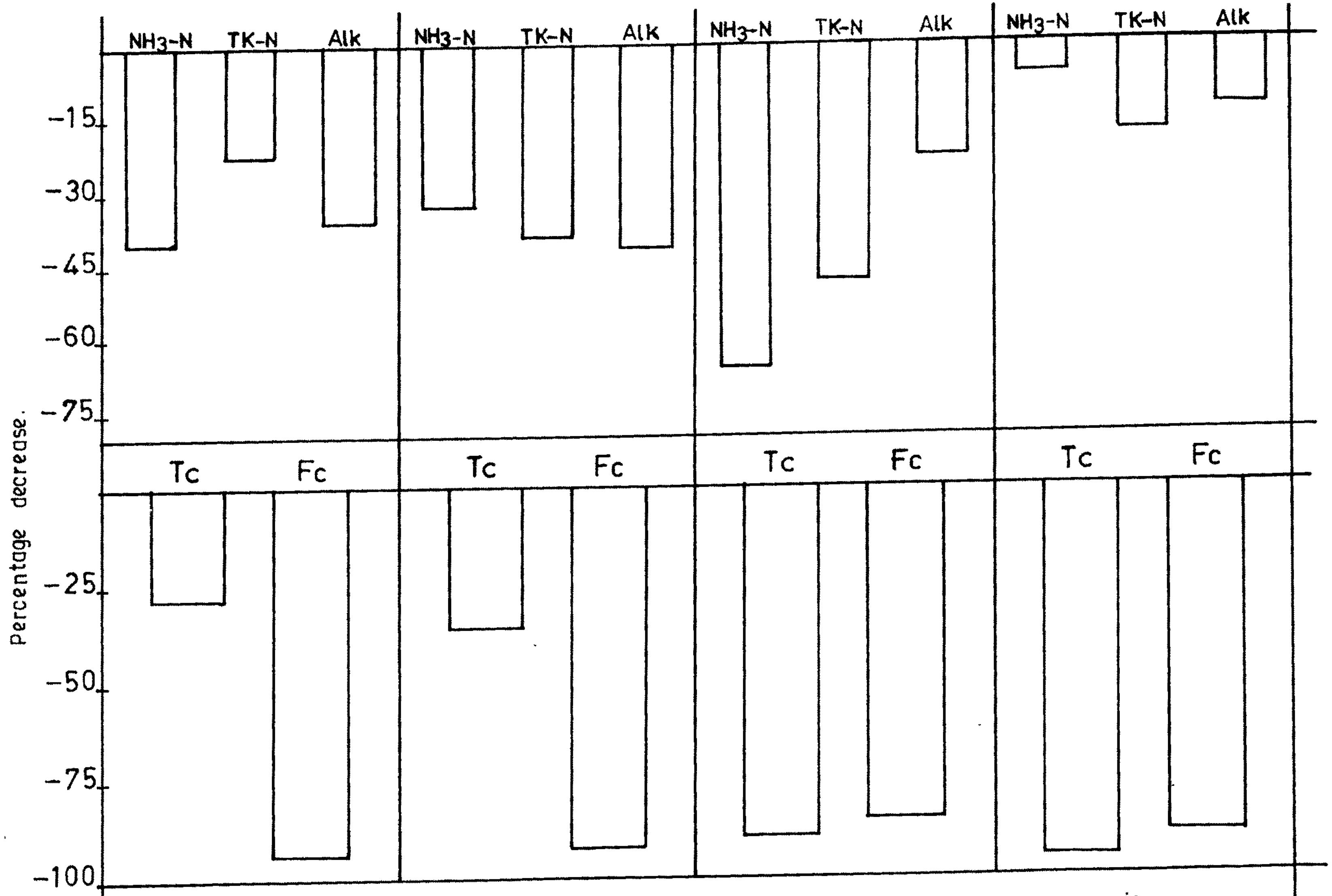


Fig 10 Percentage decrease in various physico-chemical parameters and coliform count at the Mahi estuary between 1991-1993.

J-point, at the upstream, it decreased from 838 mg/l to 72.4 mg/l and at downstream from 210 mg/l to 170.00 mg/l.

HARDNESS

The hardness of the water at all the 3 points increased consistently from 1991 to 1993. Both at the J-point and upstream, the hardness showed a very pronounced increase between 1991 and 1993. The overall increase at the 3 points from 1991 to 1993 was 1243 mg/l to 1552 mg/l (J-point), 58.2 mg/l to 87.2 mg/l (upstream) and 2427.9mg/l to 3017.1 mg/l (downstream). The changes in the hardness of water over the 3 year period at the 3 points is represented in table 13 and figures 4 and 9.

AMMONICAL NITROGEN (NH_3-N)

The NH_3-N showed a steady decrease between 1991 to 1993 at all the 3 points. The decrease at the J-point was from 5.46 mg/l to 3.67 mg/l and from 2.6mg/l to 2.5 mg/l at upstream and from 8.3 mg/l 2.84 mg/l at the downstream. The data is represented in table 14 and figures 10 and 11.

TOTAL KJELDAHL NITROGEN (TKN)

The TKN, like NH_3-N, also showed decreasing trend over the years. The values were decreased from 8.35 mg/l to 5.07

TABLE 13 : MONTHLY VARIATIONS IN HARDNESS (mg/l) AND, RANGE, MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	312	1321	3798	31	172	1661	4040	33	632	1750	4770	42
FEB	317	1496	5233	47	980	1562	2440	33	588	1600	5270	32
MAR	297	1134	5311	23	640	1359	4300	30	700	1502	4900	29
APR	299	1568	4000	38	110	1488	3819	40	900	1651	4070	66
MAY	392	1067	4332	42	152	1629	4300	42	767	1755	3927	83
JUN	300	1128	4500	61	108	1437	5600	47	447	1992	3434	36
JUL	630	1171	208	68	487	1599	261	70	600	1327	309	57
AUG	200	1081	309	77	122	1487	280	81	598	1148	409	63
SEP	178	1099	107	83	178	1607	380	97	488	1399	601	73
OCT	158	1251	42	97	520	1007	1650	67	700	1775.4	1120	77
NOV	97	1350	300	70	129	900	4500	89	1300	1150	6318	97
DEC	198	1250	117	62	180	1421	2030	89	900	1577	1078	392
MEAN	281.5	1243.0	2354.8	58.3	314.8	1429.8	2800.0	59.8	718.3	1552.2	3017.2	87.3
MIN	97	1067	42	23	108	900	261	30	447	1148	309	29
MAX	630	1568	5311	97	980	1661	5600	97	900	1992	5270	392
PERCENTAGE CHANGE FROM 1991-1993									+155.2	+24.8	+28.13	+49.6

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ``J''POINT
J - AT ``J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ``J''POINT

TABLE 14 : MONTHLY VARIATIONS IN AMMONICAL NITROGEN (NH_3-N, mg/l) AND, RANGE, MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	75.6	8.62	2.24	4	133	8.52	2.1	2	69	7.5	3.7	3.7
FEB	68	7.3	2.8	2.24	160	7.1	11	1.7	81	5.1	3.7	2.2
MAR	86.9	6.9	1.12	2.9	32.8	0.6	0.6	2.3	33	5	3.8	2.3
APR	149	8.2	2.35	3.2	37.9	7.13	3.3	3.1	40	6	2.7	2.2
MAY	37	6.2	2.24	2.7	40	6	1.2	3.1	38	5.13	1.2	3.1
JUN	127	2	19.6	3.7	27	4.3	5	3.2	27	3	1	2.7
JUL	36	3	11	2.3	30	1.9	17	2.6	16	1.2	1	1.2
AUG	24.3	2	17	2.1	22	2.7	13	1.2	19	1.5	3	2.1
SEP	25.2	4	11	2.3	39.8	1.6	1.3	2.2	22	1.6	1.3	1.1
OCT	39	8.2	12	1.7	29.7	3.8	0.8	3	30	2	1.7	2.4
NOV	120	4.5	4.5	3	25	4.04	1.4	3	57	3	7	3.1
DEC	37	4.6	14	2.2	33.6	4.03	1.2	4	60	3.07	4	4.2
MEAN	68.8	5.5	8.3	2.7	50.9	4.3	4.8	2.6	41.0	3.7	2.8	2.5
MIN	25.2	2	1.12	1.7	22	1.6	0.6	1.2	16	1.2	1	1.1
MAX	149	8.62	19.6	4	160	8.25	17	4	69	7.5	7	4.2
PERCENTAGE CHANGE FROM 1991-1993									-40.4	-32.7	-65.9	-6.1

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF "J"POINT

J - AT "J" POINT (AFTER CONFLUEN
U - UP STREAM OF "J"POINT

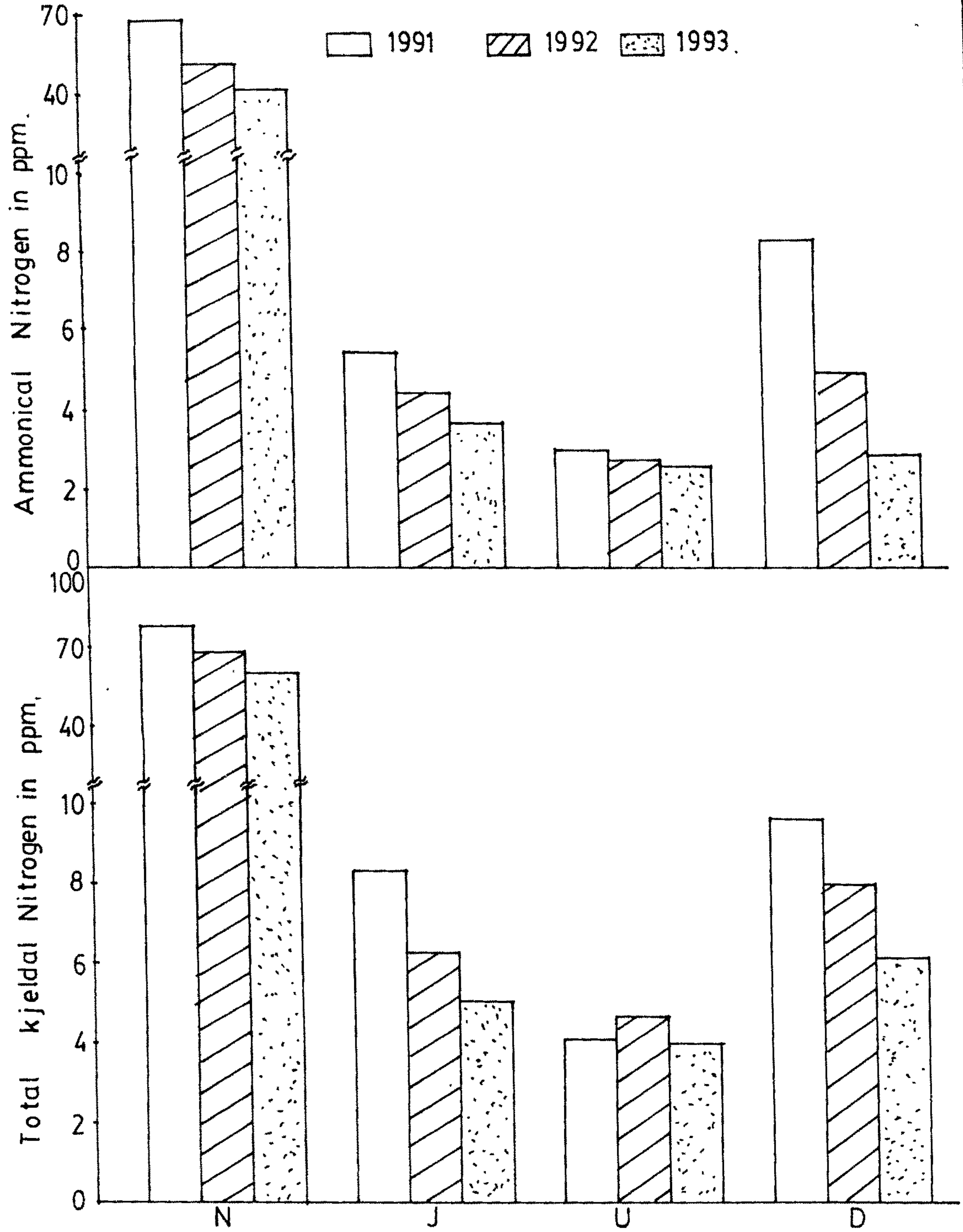


Fig.11 Average content. of Ammonical and kjeldal Nitrogen from 1991-1993 at the Mahi estuary.

N = Nahar, J = 'J' Point, U = Upstream, D = Downstream mg/l at the J-point, from 4.96 mg/l to 4.0 mg/l at the upstream and from 11.7 mg/l to 6.1 mg/l at the downstream. The values are represented in table 15 and figures 10 and 11.

OIL AND GREASE

The data recorded in table 16 and figures 2 and 12 shows definite increase of oil and grease content at all the 3 points over the 3 years of study. The content which was 1.8 mg/l at the J-point, 1.75 mg/l at the upstream and 1.84 mg/l at the downstream in 1991 increased to 2.75 mg/l, 2.4 mg/l and 3.18 mg/l respectively in 1993.

PHENOL

The phenol content at both the J-point and the upstream showed perceptible increase of over 909% and 3678% respectively from 1991 to 1993. The values recorded were 0.039mg/l in 1991 and 0.397 mg/l in 1993 at the J-point and, 0.018 mg/l in 1991 and 0.68 mg/l in 1993 at the upstream. The increase at the downstream was of lesser magnitude (from 0.06 mg/l to 0.11mg/l.) These changes are shown in table 17 and figures 4 and 12.

TAELE 15 : MONTHLY VARIATIONS IN TOTAL KJELDAHL NITROGEN (TKN, mg/l) AND, RANGE,MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	147	10.12	3.7	4.8	83.	10.17	3	4	62	8.1	6.96	4.3
FEB	123	9.3	3.7	2.9	98	9.21	15	3.8	67	6.84	7.06	4.2
MAR	111	9.89	2.7	3.7	120	8.11	2	4.3	57	6.12	6.96	5.7
APR	60	9.87	3.3	4.1	101	8.45	4	5	52.2	5.88	5.96	4.3
MAY	27	5	2.3	3.2	69	8.12	4	5.2	47	8	4.46	3
JUN	30	7	22	4.2	44.8	5.37	5	5.2	33	4	4.26	2
JUL	40	9	13	4.1	42	2.19	19	4.6	54	3.7	4.26	2
AUG	29	11	19	4.2	52	2.82	16	3.2	46	2.4	6.26	3.5
SEP	51	9.01	13	4.2	27	4.31	6	4.4	82	3.9	4.96	1.7
OCT	50.8	8.8	13	4	29	4.81	6	5	62	3.7	4.56	2.7
NOV	120	6.09	5.1	4.7	98	5.22	9	5	63	4.22	10.26	9
DEC	140	5.12	15.14	4.6	69	6.82	7	6	96	4.03	7.26	6
MEAN	77.4	8.4	9.7	4.1	69.4	6.3	8.0	4.6	60.1	5.1	6.1	4.0
MIN	27	5	2.3	2.9	6.94	2.19	3	3.2	33	2.4	4.26	1.7
MAX	143	10.12	22	4.8	120	10.17	19	6	96	8.11	10.26	9
PERCENTAGE CHANGE FROM 1991-1993									-22.4	-39.4	-48.0	-18.8

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J''POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J''POINT

TABLE 16 : MONTHLY VARIATIONS IN OIL AND GREASE (OG, mg/l) AND, RANGE, MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	4.8	2.5	0.4	1.8	6	2.5	2	2	6	2.5	3.2	2.2
FEB	4.2	2	4.2	2	5	2.5	1.2	2	7	2	2.4	1.8
MAR	1.6	1	1	2	4	1.5	1	1	5	3.5	6	1.4
APR	6	1.5	2	1	4	1.5	2	1	4	4	1.8	2.2
MAY	4	1	1.6	2	4	2.5	2	2	4.2	3.5	4	1
JUN	2	1	1.2	1	3.2	1	1	2	3	2	1.2	1.4
JUL	2	1	1	1.2	3.8	1	2	1	4	2	3.2	3.4
AUG	5	2.5	2	2	4.7	1	1	2	3.9	4	8.2	4
SEP	2.5	2	1.6	1	5.2	1.5	2	1	4.9	2.5	2	4.1
OCT	4	2.5	2	1	6.3	2.5	2	2	8	1	2.9	2
NOV	5	2.5	1.6	4	4	2.5	2	2	9	2.5	2	3
DEC	4	2	1.7	2	5	2.5	4	2	7	3.5	1.2	2.8
MEAN	3.8	1.8	1.7	1.8	4.6	1.9	1.9	1.7	5.5	2.8	3.2	2.4
MIN	1.6	1	0.4	1	3.2	1	1	1	3	1	1.2	1
MAX	6	2.5	6	4	6.3	2.5	4	2	9	4	8.2	4.1
PERCENTAGE CHANGE FROM 1991-1993									[illegible]	[illegible]	[illegible]	[illegible]

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J'' POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J'' POINT

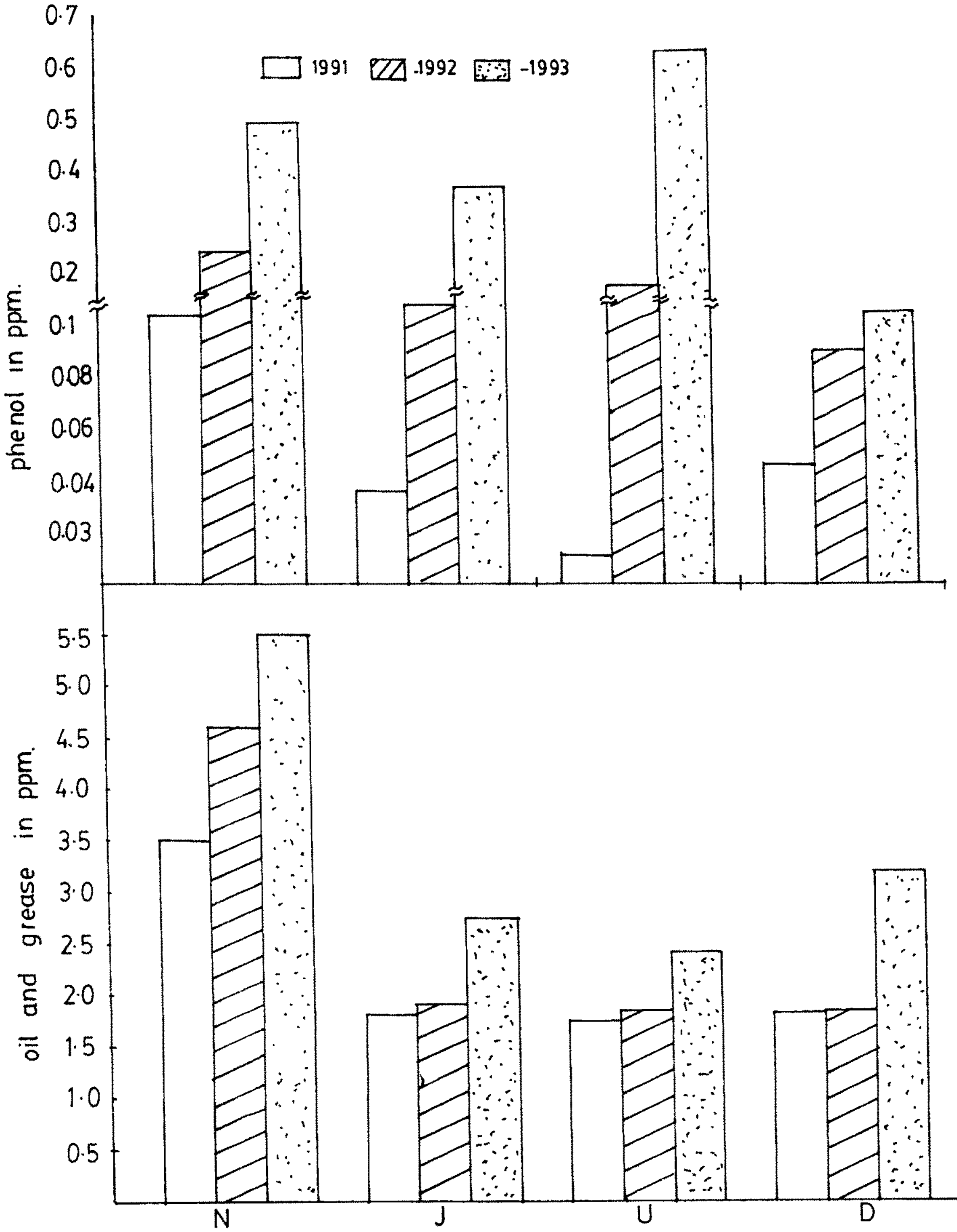


Fig.12 Average content of phenol and oil and grease from 1991-1993 at the Mahi estuary.
N=Nahar, J='J' Point, U= Upstream, D = Down stream.

TABLE 17 : MONTHLY VARIATIONS IN PHENOL (Phe, mg/l) AND, RANGE, MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	0.250	0.050	0.010	0.050	0.130	0.079	0.030	-	0.721	0.589	0.010	0.110
FEB	0.250	0.060	-	0.010	0.120	0.0823	0.010	0.011	0.213	0.132	0.105	0.080
MAR	0.300	0.030	-	0.050	0.113	0.0430	0.010	0.001	2.111	1.211	0.255	0.200
APR	0.110	0.041	0.020	0.010	0.100	0.0691	0.010	0.010	0.666	0.562	0.040	0.010
MAY	0.124	0.040	0.010	0.001	0.211	0.1630	0.110	0.010	0.511	0.401	0.630	0.130
JUN	0.200	0.002	0.010	0.001	0.121	0.0040	0.110	0.010	0.310	0.013	0.010	0.030
JUL	0.007	0.001	0.200	0.010	0.020	0.0150	0.050	0.500	0.052	0.027	0.030	1.100
AUG	0.021	0.010	0.100	0.010	0.121	0.0200	0.700	0.100	0.158	0.127	0.010	2.100
SEP	0.022	0.017	0.100	-	0.200	0.0990	0.050	0.300	0.200	0.133	0.020	0.900
OCT	0.060	0.053	0.100	-	0.810	0.5590	0.020	0.700	0.151	0.111	0.125	1.100
NOV	0.025	0.013	0.020	-	0.421	0.0513	0.040	0.300	0.140	0.358	0.250	1.400
DEC	0.213	0.155	0.030	0.010	0.813	0.6170	0.020	0.300	1.200	1.101	0.110	1.000
MEAN	0.132	0.039	0.050	0.013	0.265	0.150	0.097	0.187	0.536	0.397	0.133	0.680
MIN	0.007	0.001	0.010	0.001	0.020	0.015	0.010	0.001	0.031	0.013	0.010	0.010
MAX	0.300	0.155	0.200	0.050	0.813	0.617	0.700	0.700	2.111	1.211	0.255	2.100
PERCENTAGE CHANGE FROM 1991-1993									+305.7	+919.4	+167.3	+51.33

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J'' POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J'' POINT

CYANIDE (CN)

The CN content at the J-point varied from 0.018 to 0.032 mg/l from 1991 to 1993. In turn, the content at the upstream increased from 0.007 mg/l in 1991 to 0.022 mg/l in 1993 and at the downstream from 0.0285 mg/l to 0.0759 mg/l. The recorded values are shown in table 18 and figures 4 and 5).

TOTAL AND FECAL COLIFORM (TC AND FC)

Both TC and FC counts showed decline over the three year period from 1991 to 1993 by 36% and 92% respectively at the J-point. The total coliform count at the J-point, at upstream and at downstream was 1283.33, 7117.5 and 11683.3 MPN Count /100ml respectively, which decreased to 811.66, 375.0 and 1250.0 MPN count /100 ml in 1993. Similarly, the FC count in 1991 was 606.45, 487.5 and 725.4 MPN/100ml respectively which decreased to 48.33, 55.0 and 102.08 MPN /100 ml respectively in 1993. The data of both the total and fecal count is represented in table 19 and 20 and figures 10 and 13.

METALS

CHROMIUM (Cr) AND IRON (Fe)

The chromium and iron content increased over the 3 year period of study from 1991 to 1993. The Cr content at the J-

TABLE 18 : MONTHLY VARIATIONS IN CYANIDE (CN, mg/l) AND, RANGE,MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	0.231	0.052	0.06	0.001	0.042	0.032	0.072	0.001	0.269	0.0341	0.06	0.2
FEB	0.046	0.031	0.09	0.001	0.1	0.07	0.1	0.001	0.272	0.0721	0.01	0.01
MAR	0.051	0.0416	0.1	0.001	0.036	0.027	0.184	0.001	0.241	0.0271	0.05	0.002
APR	0.022	0.019	0.001	0.01	0.211	0.0046	0.017	0.001	0.073	0.057	0.002	0.001
MAY	0.0438	0.001	0.02	0.01	0.266	0.073	0.17	0.002	0.123	0.062	0.002	0.001
JUN	0.02	0.002	0.001	0.03	0.222	0.0502	0.01	0.001	0.124	0.04	0.001	0.001
JUL	0.023	0.002	0.001	0.006	0.061	0.002	0.1	0.001	0.12	0.0102	0.001	0.001
AUG	0.023	0.004	0.01	0.003	0.032	0.012	0.001	0.02	0.0696	0.002	0.001	0.002
SEP	0.301	0.013	0.01	0.002	0.123	0.005	0.001	0.001	0.366	0.015	0.07	0.003
OCT	0.303	0.019	0.01	0.002	0.095	0.004	0.01	0.1	0.369	0.022	0.1	0.02
NOV	0.3	0.018	0.01	0.001	0.07	0.05	0.002	0.02	0.262	0.032	0.128	0.02
DEC	0.019	0.016	0.01	0.02	0.2	0.02	0.005	0.05	0.4	0.02	0.41	0.01
MEAN	0.115	0.018	0.027	0.007	0.122	0.029	0.056	0.017	0.224	0.033	0.070	0.023
MIN	0.0438	0.001	0.001	0.001	0.061	0.002	0.001	0.001	0.0699	0.002	0.001	0.001
MAX	0.231	0.05	0.09	0.03	0.266	0.73	0.184	0.1	0.472	0.0721	0.41	0.2
PERCENTAGE CHANGE FROM 1991-1993									+94.7	+80.1	+165.9	+159.3

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J''POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J''POINT

TABLE 19 : MONTHLY VARIATIONS IN TOTAL COLIFORM (TC, MPN/100 ml) AND, RANGE, MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	24000	460	300	11000	460	1500	1100	150	460	460	2400	75
FEB	24000	11000	11000	24000	460	1500	2100	460	460	300	2100	150
MAR	1100	2400	24000	11000	1100	1100	2100	1100	460	750	1100	150
APR	750	1100	24000	11000	75	1100	750	750	1100	460	2100	150
MAY	750	24000	24000	11000	1100	1100	1100	2400	460	750	150	150
JUN	1100	24000	2400	11000	460	2400	1100	1100	230	1100	1100	1100
JUL	1100	11000	2400	1100	1100	1500	1100	1100	240	2400	1100	1100
AUG	750	24000	24000	1100	750	750	1100	750	75	1100	1100	1100
SEP	750	11000	1500	1500	480	1100	1100	1100	240	750	1100	150
OCT	1100	2400	1100	1500	150	1500	2100	1500	150	750	1500	150
NOV	460	1500	1500	750	150	1100	1500	1100	1500	460	1100	150
DEC	150	300	2400	460	75	750	2100	1100	240	460	150	75
MEAN	4667.5	9430.0	9883.3	7117.5	530.0	1283.3	1437.5	1050.8	467.9	811.7	1250.0	375.0
MIN	150	300	300	460	75	750	750	150	75	300	150	75
MAX	24000	24000	24000	24000	1100	2400	2100	2400	1100	2400	2400	1100
PERCENTAGE CHANGE FROM 1991-1993									-29.1	-36.8	-89.3	-94.7

* N - NAHAR (BEFORE CONFLUENCE) J - AT ''J'' POINT (AFTER CONFLUENCE)
D - DOWN STREAM OF ''J''POINT U - UP STREAM OF ''J''POINT

TABLE 20 : MONTHLY VARIATIONS IN FECAL COLIFORM (FC,MPN/100 ml) AND, RANGE,MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	30	150	230	150	280	240	150	75	70	70	150	75
FEB	70	1100	150	240	110	150	150	75	35	75	150	75
MAR	280	460	700	75	110	75	70	75	30	35	70	75
APR	150	150	700	75	30	240	75	75	35	30	75	70
MAY	30	460	930	70	30	240	75	75	70	30	75	30
JUN	2400	240	930	70	75	150	75	150	35	30	75	30
JUL	2400	460	1100	2400	70	240	150	210	30	75	150	150
AUG	2400	750	1100	2400	35	150	70	750	35	70	70	30
SEP	110	1100	2400	70	350	75	150	240	75	70	150	30
OCT	30	1100	280	75	30	75	110	150	35	35	110	30
NOV	280	1100	110	75	30	240	75	70	30	30	75	30
DEC	430	150	75	150	30	240	75	70	30	30	75	35
MEAN	717.5	601.7	725.4	487.5	98.3	176.3	102.1	167.9	42.5	48.3	102.1	55.0
MIN	30	150	110	70	30	75	70	70	30	30	70	30
MAX	2400	1100	2400	2400	350	240	150	750	75	75	150	150
PERCENTAGE CHANGE FROM 1991-1993									-94.1	-92.0	-85.9	-88.7

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J''POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J''POINT

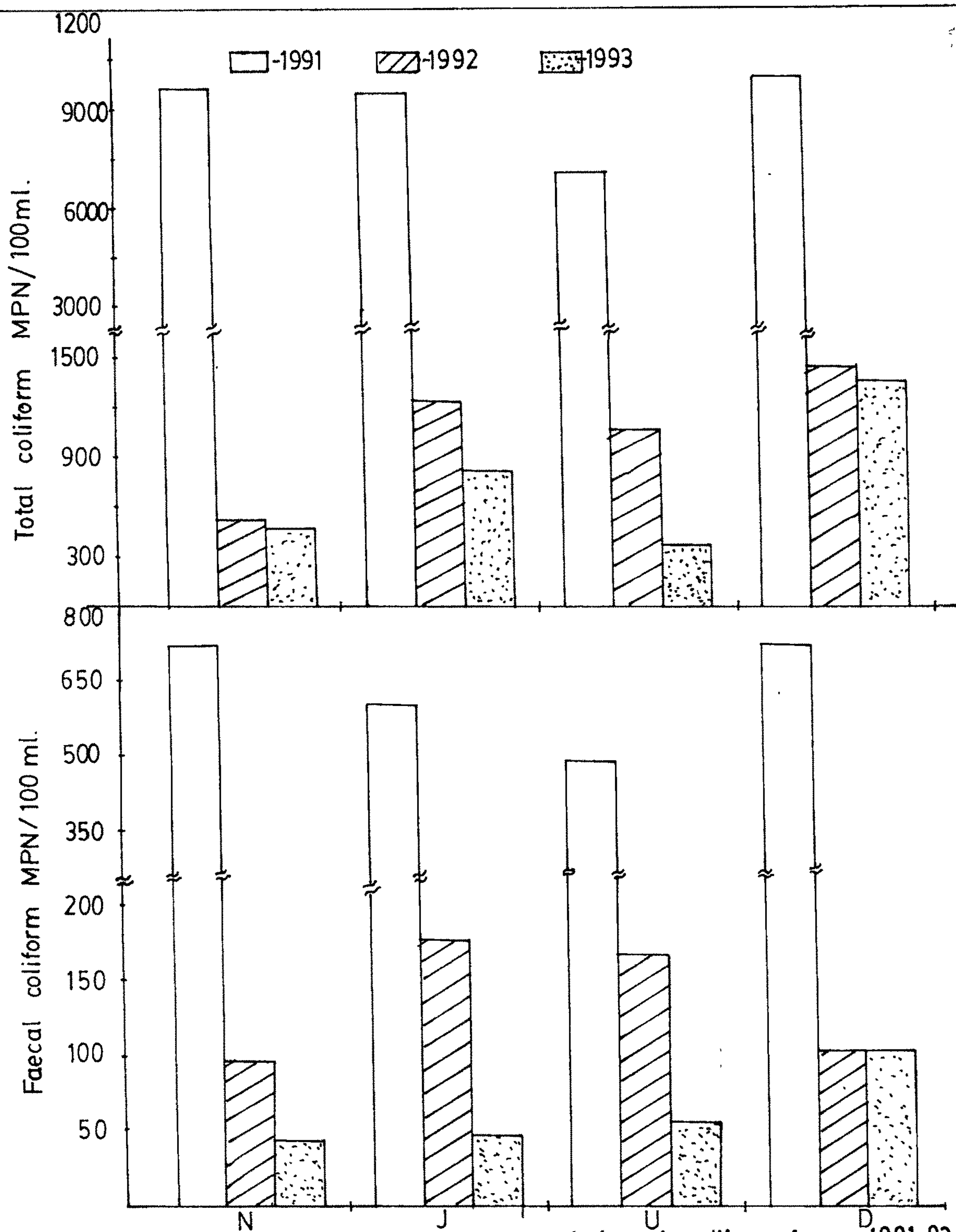


Fig13 Average Concentration of total and faecal coliform from 1991-93 at the Mahi estuary.

N - Nahar, J-"J" Point, U - Upstream, D - Down stream.

point, at upstream and at downstream was 0.048 mg/l, 0.0145 mg/l and 0.0188 mg/l respectively in 1991 which increased to 0.1422, 0.1329 and 0.1028 mg/l respectively in 1993, an increase of 195% at J-point, 816% at upstream and 27% at downstream. Similarly, the Fe content was 0.0127 mg/l, 0.018 mg/l and 0.0045 mg/l in 1991 which increased to 0.3875 mg/l, 0.720 mg/l and 0.0183 mg/l respectively in 1993, an increase of 2884.6% at J Point, 3333.33% at up stream and 307% at downstream. The data is shown in tables 21 and 22 and figures 14 - 16).

NICKEL (Ni) AND COPPER (Cu)

The data on Ni and Cu for the 3 years period of study is represented in tables 23 and 24 and figures 14, 16 and 17. The Ni content at the J-point, at upstream and at downstream was 0.01666, 0.0144, 0.0183 mg/l in 1991 which increased to 0.18424, 0.2961 and 0.0755 mg/l in 1993, an increase of 995.9% at the J-point, 1476% at upstream and 312.5% at downstream. Similarly, the Cu content was 0.0449 at the J-point, 0.0535 at upstream and 0.08083 mg/l at downstream in 1991 which increased to 0.199, 0.2012 and 0.1932 mg/l respectively in 1993, an increase of 201.5% at the J-point, 282% at up stream and 139% at downstream.

TABLE 21 : MONTHLY VARIATIONS IN CHROMIUM (Cr; mg/l) AND; RANGE,MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	0.117	0.107	0.003	0.004	0.103	0.101	0.37	0.002	0.413	0.311	0.047	0.11
FEB	0.02	0.013	0.003	0.002	0.163	0.124	0.383	0.002	0.311	0.152	0.148	0.2
MAR	0.06	0.057	0.097	0.004	0.064	0.043	0.074	0.011	0.4316	0.136	0.047	0.103
APR	0.04	0.038	0.06	0.09	0.083	0.06	0.03	0.03	0.101	0.099	0.48	0.017
MAY	0.088	0.077	0.403	0.03	0.099	0.048	0.02	0.03	0.389	0.321	0.152	0.002
JUN	0.002	0.001	0.006	0.004	0.025	0.02	0.01	0.09	0.414	0.362	0.052	0.001
JUL	0.006	0.003	0.001	0.001	0.009	0.004	0.03	0.02	0.008	0.003	0.036	0.001
AUG	0.006	0.004	0.01	0.002	0.005	0.003	0.06	0.07	0.01	0.006	0.03	0.002
SEP	0.004	0.003	0.048	0.001	0.012	0.009	0.06	0.09	0.062	0.04	0.03	0.019
OCT	0.04	0.03	0.168	0.011	0.025	0.019	0.01	0.07	0.123	0.099	0.03	0.11
NOV	0.182	0.173	0.145	0.02	0.099	0.09	0.003	0.03	0.072	0.051	0.1	0.12
DEC	0.089	0.072	0.03	0.005	0.198	0.129	0.013	0.002	0.147	0.127	0.112	0.91
MEAN	0.055	0.048	0.081	0.015	0.074	0.054	0.089	0.037	0.207	0.142	0.105	0.133
MIN	0.002	0.001	0.001	0.001	0.005	0.003	0.003	0.002	0.011	0.003	0.03	0.001
MAX	0.182	0.173	0.168	0.09	0.198	0.129	0.383	0.09	0.4316	0.362	0.152	0.91
PERCENTAGE CHANGE FROM 1991-1993									+279.4	+195.3	+27	+816

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J'' POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J'' POINT

TABLE 22 : MONTHLY VARIATIONS IN IRON (Fe, mg/l) AND, RANGE,MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	0.049	0.009	0.001	0.003	0.141	0.1	0.003	0.002	0.421	0.21	0.004	0.009
FEB	0.082	0.009	0.001	0.001	0.023	0.013	0.002	0.002	0.733	0.23	0.002	1.109
MAR	0.022	0.013	0.002	0.003	0.073	0.006	0.002	0.003	1.512	0.41	0.003	1.037
APR	0.017	0.009	0.003	0.004	0.089	0.008	0.003	0.003	1.201	0.44	0.003	1.111
MAY	0.075	0.017	0.003	0.037	0.031	0.029	0.003	0.041	0.627	0.03	0.013	1.027
JUN	0.032	0.021	0.004	0.029	0.029	0.026	0.009	0.034	0.587	0.12	0.041	0.022
JUL	0.009	0.008	0.005	0.031	0.012	0.009	0.007	0.033	0.819	0.14	0.033	0.021
AUG	0.004	0.002	0.006	0.034	0.009	0.003	0.008	0.037	0.933	0.08	0.047	0.029
SEP	0.019	0.017	0.006	0.004	0.021	0.011	0.007	0.029	0.06	0.04	0.028	0.011
OCT	0.022	0.013	0.007	0.03	0.027	0.016	0.009	0.031	0.08	0.06	0.018	1.033
NOV	0.029	0.023	0.007	0.003	0.031	0.027	0.011	0.033	1.97	1.76	0.011	0.999
DEC	0.028	0.012	0.009	0.037	0.021	0.013	0.011	0.033	1.62	1.13	0.017	1.003
MEAN	0.032	0.013	0.005	0.018	0.042	0.022	0.006	0.023	0.880	0.388	0.018	0.618
MIN	0.004	0.002	0.001	0.002	0.009	0.003	0.002	0.003	0.06	0.04	0.002	0.021
MAX	0.082	0.023	0.009	0.041	0.141	0.1	0.011	0.037	1.97	1.76	0.047	1.111
PERCENTAGE CHANGE FROM 1991-1993									+2650	+2884.6	+306.6	+3333.3

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J'' POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J'' POINT

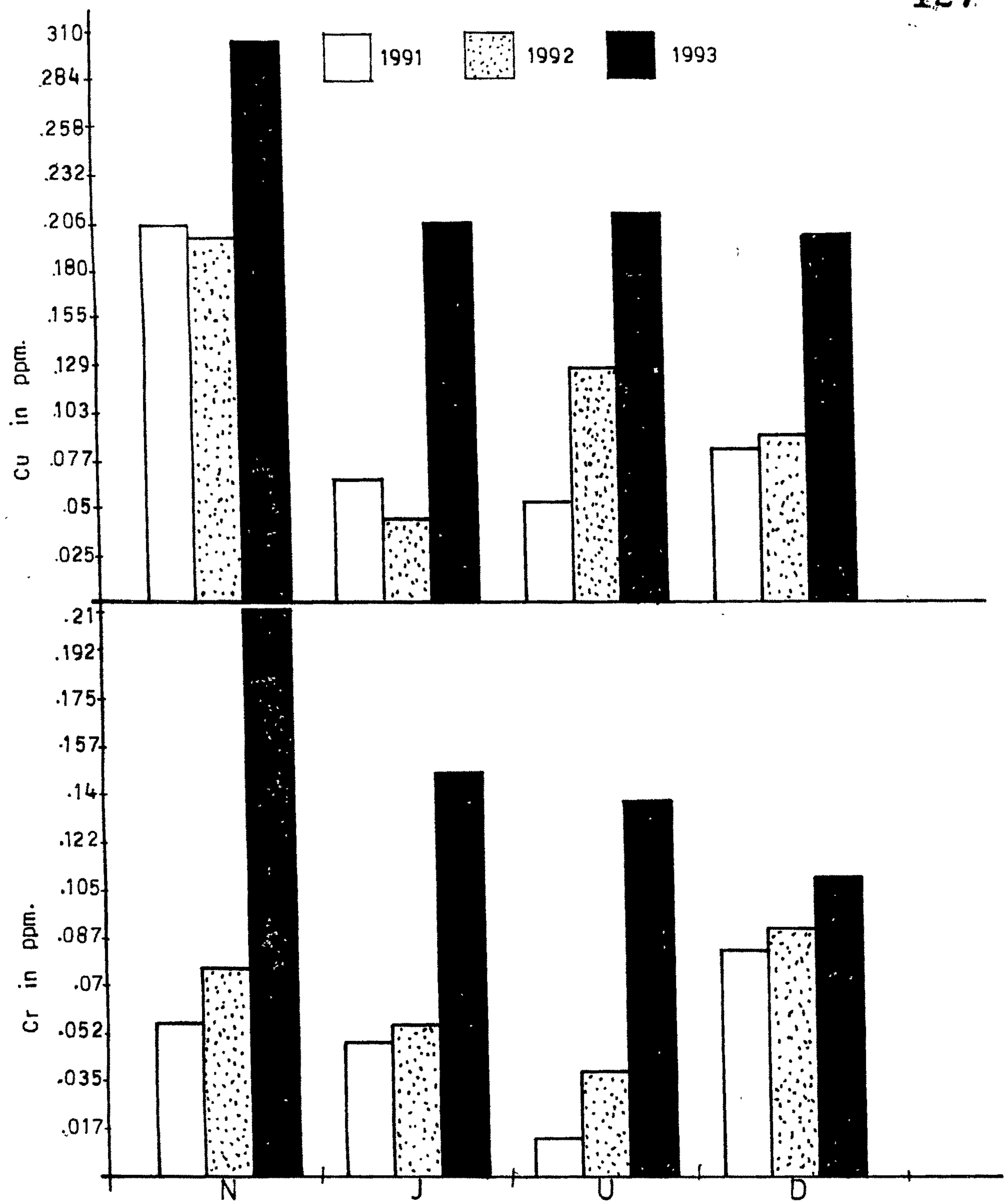


Fig 14 Average Copper (Cr) and Chromium (Cr) content at Mahi estuary between 1991-1993.
N-Nahar, J-J point, U-Upstream, D-Downstream.

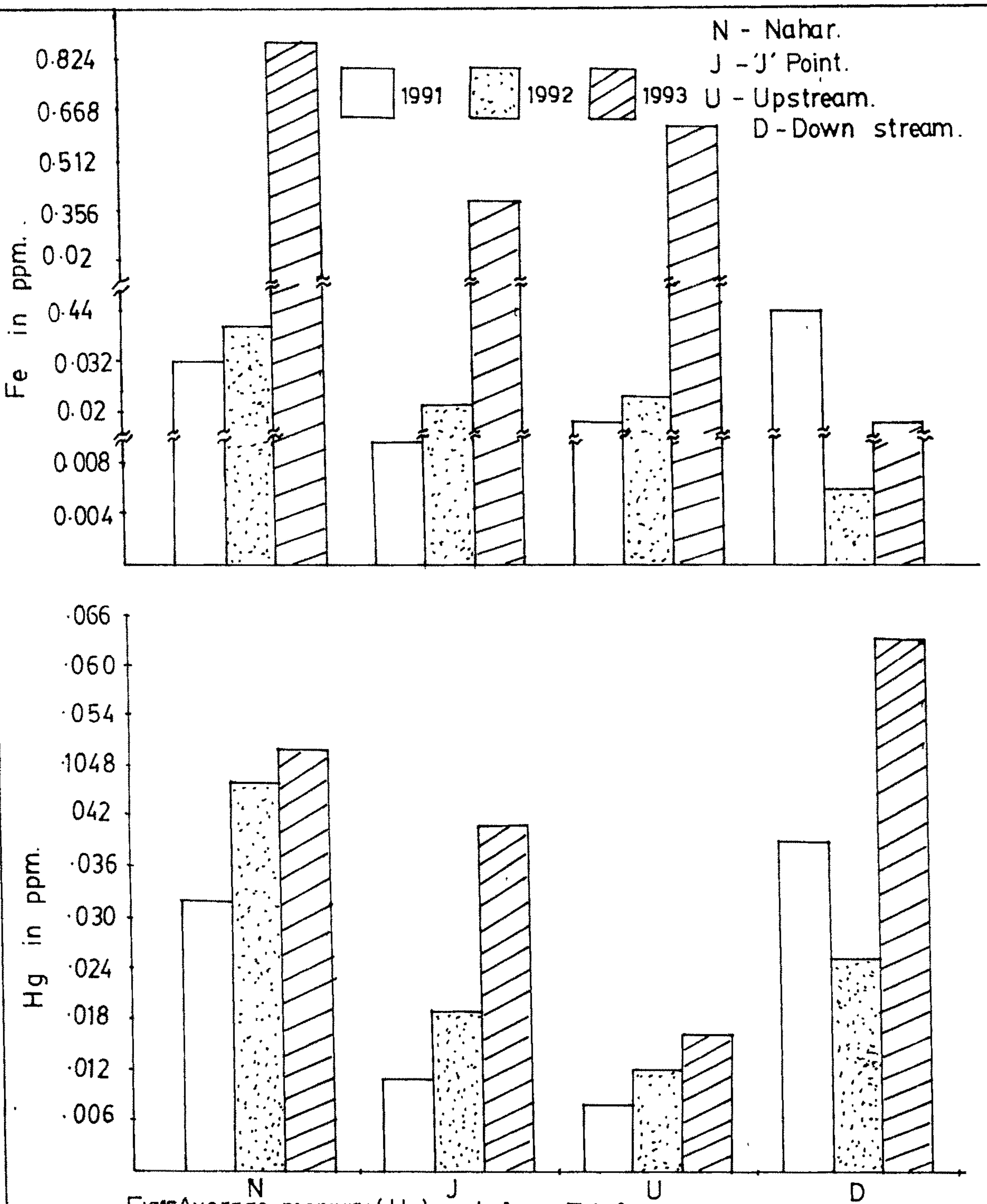


Fig15 Average mercury (Hg) and Iron (Fe) Content between 1991-1993. at the Mahi estuary.

N= Nahar, J='J'Point, U = Upstream; D = Downstream.

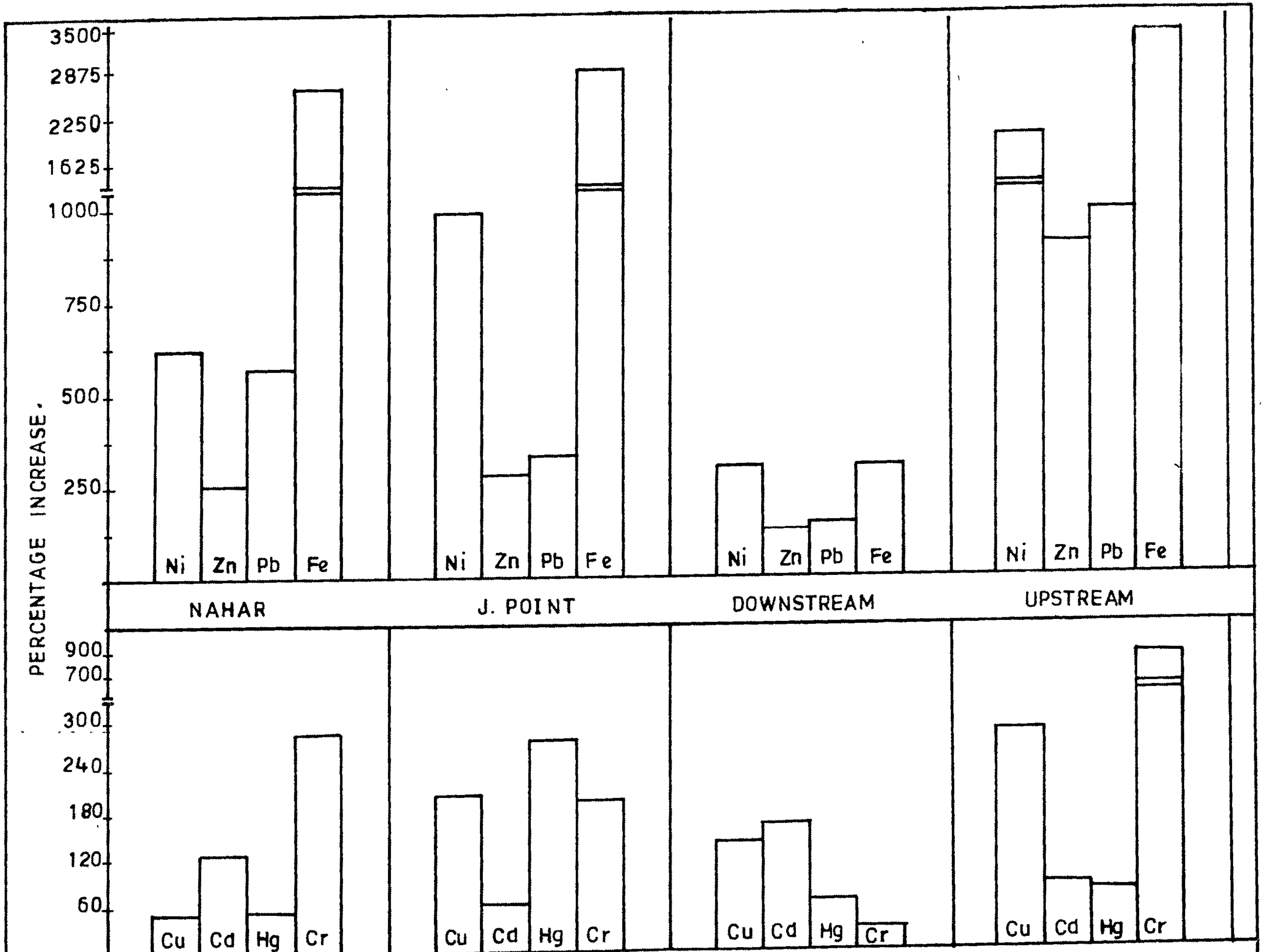


Fig.16 PERCENTAGE INCREASE OF VARIOUS METALS FROM 1991-1993 AT MAHI ESTUARY.

TABLE 23 : MONTHLY VARIATIONS IN NICKEL (Ni, mg/l) AND, RANGE,MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	. 1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	0.083	0.02	0.01	0.013	0.107	0.073	0.1	0.11	0.041	0.012	0.11	1.21
FEB	0.062	0.017	0.07	0.011	0.009	0.099	0.1	0.02	0.039	0.039	0.11	1
MAR	0.059	0.019	0.056	0.03	0.219	0.057	0.07	0.03	0.103	0.099	0.229	0.03
APR	0.069	0.024	0.04	0.002	0.813	0.069	0.01	0.021	1.8316	0.119	0.02	0.011
MAY	0.071	0.035	0.003	0.001	0.666	0.079	0.01	0.02	0.523	0.217	0.032	0.311
JUN	0.013	0.001	0.002	0.001	0.822	0.028	0.03	0.007	0.999	0.707	0.025	0.03
JUL	0.014	0.001	0.002	0.001	0.079	0.006	0.02	0.01	0.022	0.004	0.02	0.003
AUG	0.021	0.002	0.002	0.001	0.058	0.006	0.03	0.01	0.017	0.007	0.01	0.005
SEP	0.049	0.002	0.001	0.002	0.099	0.007	0.035	0.01	0.032	0.019	0.03	0.01
OCT	0.083	0.011	0.013	0.002	0.213	0.019	0.06	0.06	0.092	0.032	0.03	0.012
NOV	0.107	0.033	0.011	0.002	0.109	0.027	0.01	0.03	0.768	0.5	0.12	0.012
DEC	0.092	0.035	0.01	0.107	0.217	0.118	0.004	0.07	0.786	0.481	0.15	0.09
MEAN	0.060	0.017	0.018	0.014	0.284	0.049	0.040	0.033	0.438	0.186	0.074	0.227
MIN	0.013	0.001	0.001	0.001	0.058	0.006	0.004	0.01	0.022	0.004	0.02	0.005
MAX	0.107	0.035	0.056	0.107	0.822	0.118	0.1	0.11108316		0.707	0.229	1.21
PERCENTAGE CHANGE FROM 1991-1993									+629.6	+995.9	+312.5	+1476

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J'' POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J'' POINT

TABLE 24 : MONTHLY VARIATIONS IN COPPER (Cu, mg/l) AND, RANGE,MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	0.307	0.1	0.128	0.113	0.427	0.061	0.158	0.107	0.107	0.225	0.139	0.22
FEB	0.271	0.169	0.17	0.111	0.319	0.062	0.11	0.311	0.412	0.219	0.405	1.2
MAR	0.093	0.052	0.082	0.013	0.411	0.057	0.09	0.01	0.041	0.012	0.63	0.05
APR	0.087	0.04	0.08	0.01	0.35	0.079	0.09	0.03	0.043	0.014	0.107	0.02
MAY	0.182	0.099	0.04	0.01	0.388	0.068	0.089	0.21	0.21	0.12	0.209	0.03
JUN	0.027	0.012	0.09	0.01	0.033	0.029	0.03	0.11	0.517	0.219	0.011	0.117
JUL	0.5395	0.025	0.01	0.002	0.027	0.005	0.03	0.01	1.211	0.801	0.003	0.005
AUG	0.099	0.005	0.01	0.005	0.019	0.007	0.06	0.009	0.102	0.077	0.001	0.008
SEP	0.0875	0.009	0.04	0.003	0.027	0.007	0.07	0.07	0.097	0.032	0.02	0.211
OCT	0.321	0.025	0.09	0.061	0.041	0.02	0.09	0.11	0.111	0.073	0.258	0.3
NOV	0.2[illegible]	0.178	0.1	0.09	0.039	0.026	0.12	0.211	0.096	0.085	0.227	0.08
DEC	0.162	0.099	0.13	0.215	0.217	0.118	0.112	0.3	0.679	0.511	0.309	0.21
MEAN	0.199	0.068	0.081	0.054	0.192	0.045	0.087	0.124	0.302	0.199	0.193	0.204
MIN	0.027	0.005	0.01	0.002	0.019	0.005	0.03	0.009	0.041	0.032	0.001	0.005
MAX	0.5395	0.178	0.17	0.215	0.427	0.118	0.158	0.311	1.211	0.801	0.309	1.2
PERCENTAGE CHANGE FROM 1991-1993									+52	+201.5	+139	+282

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J''POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J''POINT

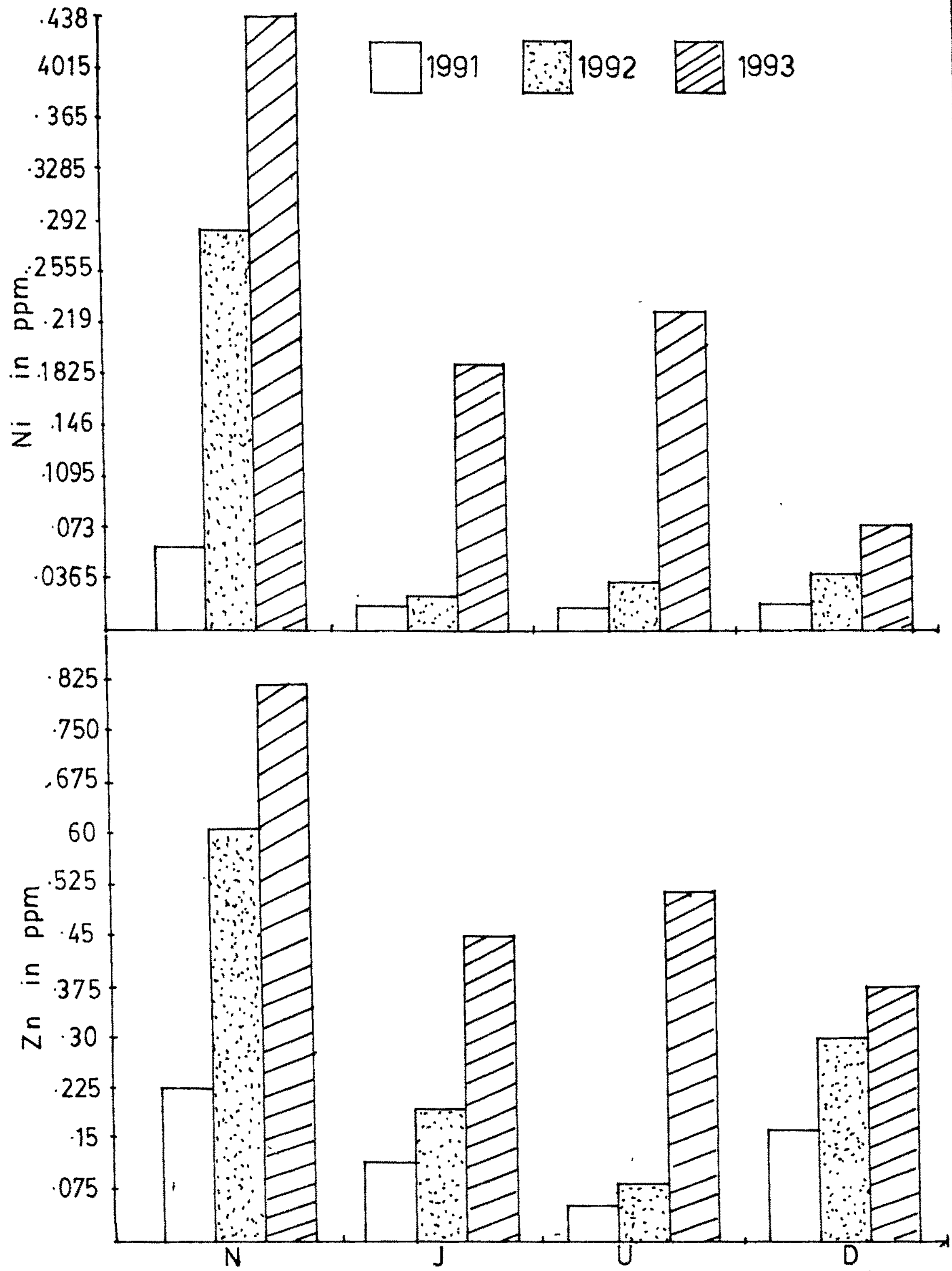


Fig17Averary Concentration of Nickel (Ni) and Zinc (Zn) at the Mahi estuary between 1991-93.

N=Nahar, J=J' Point, U=Upstream, D= Down stream

ZINC (Zn) AND CADMIUM (Cd)

Both Zn and Cd content increased in the 3 year study period, as represented in table 25 and 26 and figures 16-18. The Zn content at the J-point, at upstream an at downstream was 0.115, 0.0516 and 0.1787 mg/l respectively in 1991 which increased to 0.4477, 0.5164 & 0.3776 mg/l respectively in 1993, an increase of 289% at the J-point, 900% at upstream and 111.7% at downstream. Similar trend was shown by Cd, which increased from 0.01625 at the J-point, 0.01266 at upstream and 0.01958 mg/l at downstream in 1991 to 0.02652, 0.02366 and 0.02975 mg/l respectively in 1993. There was an increase of 64.3% at the J-point, 81.18% at upstream and 73.33% at downstream.

LEAD (Pb) AND MERCURY (Hg)

There was significant increase in the content of Pb and Hg over the three year period of study which is depicted in tables 27 and 28 and figures 15,16 and 18. The Pb content at the J-point, at upstream and at downstream was 0.0952, 0.0431 and 0.1421 mg/l respectively in 1991 which increased to 0.41266, 0.4694 & 0.3555 mg/l respectively in 1993, indicating an increase of 346% at the J-point, 989% at upstream and 150% at downstream. Similarly, Hg showed increase from 0.01108 mg/l at the J-Point, 0.0095mg/l at up

TABLE 25 : MONTHLY VARIATIONS IN ZINC (Zn, mg/l) AND, RANGE, MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	0.421	0.21	0.102	0.123	0.721	0.215	0.314	0.11	0.998	0.461	1.11	1.37
FEB	0.513	0.147	0.1	0.054	0.673	0.209	0.1	0.11	0.926	0.622	0.51	0.22
MAR	0.417	0.236	0.1	0.009	0.499	0.012	0.26	0.09	1.213	0.57	0.731	0.07
APR	0.462	0.198	0.11	0.014	0.673	0.114	0.104	0.09	0.868	0.79	0.607	0.072
MAY	0.409	0.291	0.021	0.015	0.541	0.201	0.11	0.031	0.9262	0.68	0.186	0.025
JUN	0.048	0.029	0.1	0.001	0.763	0.207	0.32	0.09	0.523	0.29	0.02	0.028
JUL	0.018	0.004	0.11	0.001	1.21	0.6	0.05	0.01	0.11	0.05	0.086	0.562
AUG	0.013	0.005	0.2	0.004	0.213	0.072	0.01	0.035	0.123	0.06	0.012	0.99
SEP	0.041	0.002	0.21	0.017	0.021	0.004	0.219	0.036	0.723	0.08	0.038	0.12
OCT	0.031	0.007	0.22	0.153	0.124	0.041	0.63	0.09	1.213	0.22	0.012	0.21
NOV	0.098	0.053	0.269	0.119	0.367	0.136	0.264	0.11	0.917	0.36	0.1	1.3
DEC	0.217	0.198	0.414	0.11	1.511	0.52	1.211	0.21	1.313	1.19	1.12	1.23
MEAN	0.224	0.115	0.163	0.052	0.610	0.194	0.299	0.084	0.821	0.448	0.378	0.516
MIN	0.013	0.002	0.102	0.001	0.021	0.004	0.01	0.01	0.11	0.05	0.012	0.025
MAX	0.513	0.291	0.414	0.153	1.511	0.6	1.211	0.36	1.313	1.19	1.12	1.37
PERCENTAGE CHANGE FROM 1991-1993									+266.5	+289.3	+111.7	+900

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J'' POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J'' POINT

TABLE 26 : MONTHLY VARIATIONS IN CADMIUM (Cd, mg/l) AND, RANGE,MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	0.0234	0.02	0.029	0.019	0.05	0.045	0.031	0.021	0.103	0.0512	0.091	0.034
FEB	0.03	0.023	0.02	0.019	0.037	0.035	0.33	0.027	0.112	0.0411	0.045	0.036
MARCH	0.027	0.017	0.039	0.018	0.029	0.023	0.035	0.022	0.121	0.035	0.039	0.034
APR	0.03	0.022	0.037	0.019	0.04	0.034	0.037	0.027	0.104	0.043	0.041	0.036
MAY	0.04	0.024	0.002	0.001	0.02	0.013	0.029	0.025	0.031	0.025	0.004	0.033
JUN	0.004	0.002	0.002	0.005	0.019	0.012	0.002	0.003	0.029	0.023	0.005	0.003
JUL	0.003	0.001	0.002	0.002	0.003	0.002	0.002	0.003	0.009	0.003	0.003	0.004
AUG	0.003	0.002	0.002	0.001	0.009	0.006	0.004	0.004	0.009	0.004	0.003	0.004
SEP	0.005	0.002	0.004	0.002	0.083	0.004	0.027	0.019	0.012	0.004	0.003	0.005
OCT	0.059	0.03	0.007	0.022	0.042	0.031	0.027	0.022	0.053	0.032	0.042	0.03
NOV	0.039	0.02	0.041	0.021	0.086	0.022	0.037	0.023	0.06	0.024	0.039	0.032
DEC	0.051	0.032	0.03	0.023	0.041	0.032	0.033	0.021	0.06	0.033	0.042	0.033
MEAN	0.022	0.014	0.015	0.011	0.033	0.019	0.042	0.016	0.050	0.023	0.026	0.020
MIN	0.003	0.001	0.002	0.001	0.003	0.002	0.002	0.003	0.009	0.003	0.003	0.003
MAX	0.059	0.032	0.041	0.23	0.086	0.045	0.037	0.027	0.121	0.0512	0.091	0.036
PERCENTAGE CHANGE FROM 1991-1993									+127.3	+64.3	+73.33	+81.1

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J''POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J''POINT

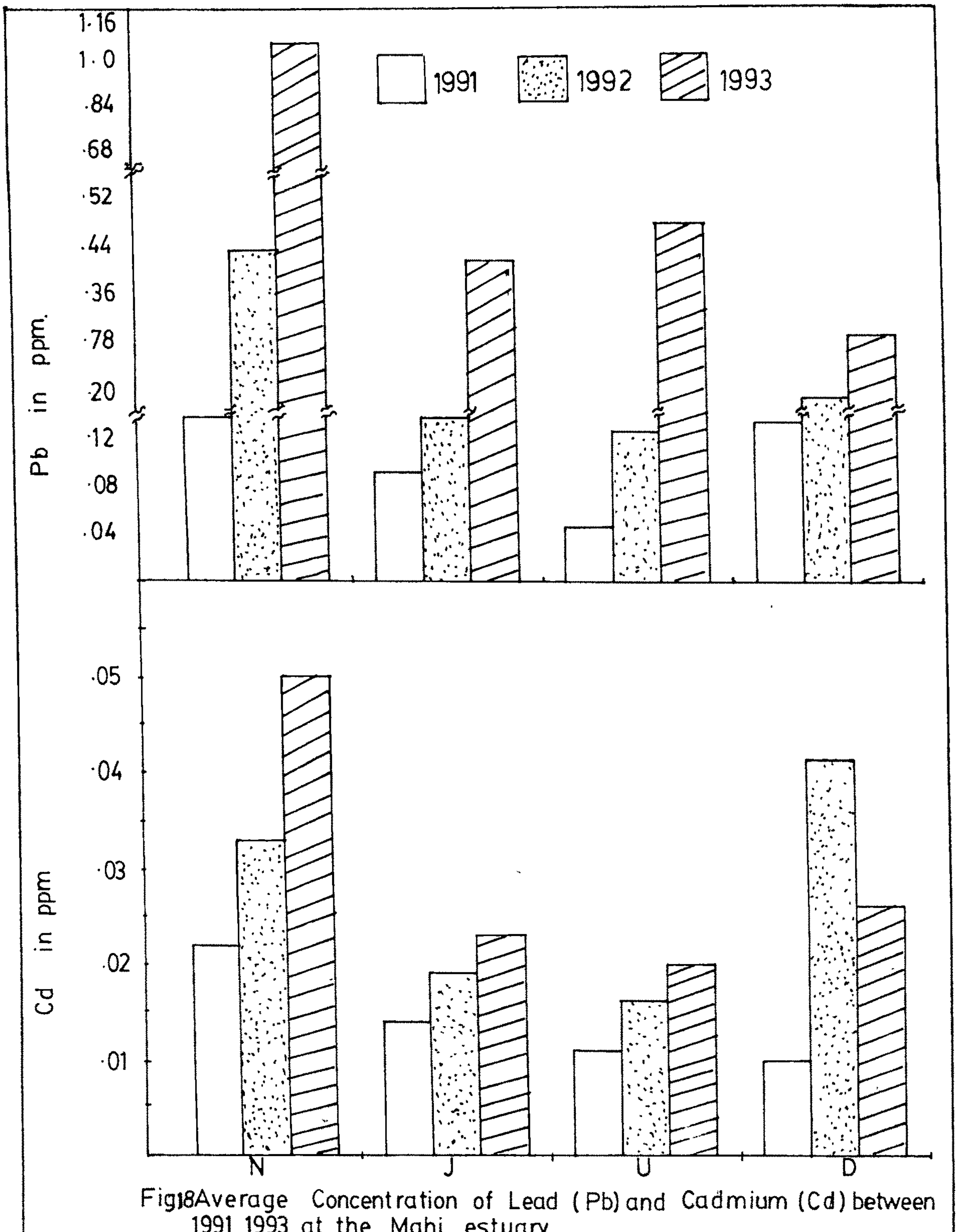


Fig.18 Average Concentration of Lead (Pb) and Cadmium (Cd) between 1991 1993 at the Mahi estuary.
N=Nahar, J='J'point, U=Upstream, D=Down stream.

TABLE 27 : MONTHLY VARIATIONS IN LEAD (Pb, mg/l) AND, RANGE, MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	0.153	0.101	0.137	0.213	0.417	0.202	0.356	0.101	1.237	0.807	0.315	1.27
FEB	0.164	0.117	0.185	0.131	0.631	0.309	0.301	0.112	0.829	0.325	0.75	1.27
MAR	0.312	0.213	0.366	0.012	0.319	0.219	0.31	0.131	1.535	0.217	0.318	1.5
APR	0.354	0.168	0.113	0.017	0.339	0.273	0.12	0.146	1.0034	0.766	0.1	0.075
MAY	0.427	0.286	0.36	0.023	1.213	0.293	0.099	0.1	0.869	0.707	0.04	0.035
JUN	0.051	0.026	0.003	0.001	1.296	0.035	0.09	0.098	0.998	0.546	0.04	0.09
JUL	0.005	0.003	0.003	0.003	0.019	0.007	0.21	0.087	0.967	0.005	0.089	0.07
AUG	0.013	0.005	0.001	0.002	0.21	0.106	0.11	0.063	0.879	0.619	0.04	0.022
SEP	0.009	0.003	0.004	0.001	0.009	0.004	0.103	0.067	1.213	0.503	0.089	0.021
OCT	0.012	0.007	0.02	0.003	0.017	0.006	0.11	0.029	0.986	0.007	0.31	0.031
NOV	0.121	0.051	0.173	0.002	0.413	0.203	0.15	0.29	0.869	0.225	0.5	0.069
DEC	0.241	0.131	0.34	0.11	0.3139	0.207	0.21	0.33	1.211	0.225	0.88	1.23
MEAN	0.155	0.093	0.142	0.043	0.433	0.155	0.181	0.130	1.050	0.413	0.289	0.474
MIN	0.009	0.003	0.09	0.001	0.009	0.004	0.09	0.053	0.869	0.005	0.04	0.04
MAX	0.427	0.213	0.356	0.213	1.296	0.309	0.356	0.33	11.535	0.807	0.88	1.5
PERCENTAGE CHANGE FROM 1991-1993									+576	+346.1	+150	+989

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J''POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J''POINT

TABLE 28 : MONTHLY VARIATIONS IN MERCURY (Hg, mg/l) AND, RANGE, MEAN AND PERCENTAGE CHANGE AT THE MAHI ESTUARY FROM 1991-1993

YEAR	1991				1992				1993			
POINT*/ MONTH	N	J	D	U	N	J	D	U	N	J	D	U
JAN	0.0202	0.02	0.39	0.01	0.057	0.03	0.01	0.01	0.037	0.033	0.224	0.013
FEB	0.099	0.004	0.036	0.01	0.069	0.007	0.01	0.01	0.021	0.012	0.28	0.017
MAR	0.123	0.01	0.03	0.01	0.0706	0.02	0.035	0.093	0.05	0.03	0.003	0.011
APR	0.033	0.02	0.01	0.02	0.069	0.018	0.01	0.013	0.023	0.019	0.003	0.0411
MAY	0.005	0.003	0.01	0.01	0.08	0.06	0.01	0.003	0.013	0.009	0.01	0.0305
JUN	0.031	0.01	0.002	0.001	0.07	0.02	0.003	0.004	0.018	0.03	0.01	0.006
JUL	0.021	0.01	0.002	0.003	0.05	0.03	0.01	0.003	0.018	0.015	0.01	0.007
AUG	0.003	0.01	0.001	0.001	0.004	0.01	0.002	0.005	0.017	0.002	0.001	0.003
SEP	0.003	0.001	0.004	0.001	0.004	0.002	0.002	0.003	0.023	0.001	0.003	0.004
OCT	0.002	0.001	0.004	0.002	0.006	0.002	0.01	0.003	0.021	0.003	0.02	0.021
NOV	0.051	0.03	0.006	0.01	0.071	0.02	0.01	0.009	0.213	0.199	0.025	0.017
DEC	0.03	0.023	0.007	0.03	0.051	0.025	0.214	0.002	0.199	0.174	0.23	0.031
MEAN	0.032	0.011	0.039	0.008	0.046	0.019	0.025	0.012	0.050	0.041	0.063	0.016
MIN	0.002	0.001	0.001	0.001	0.004	0.001	0.002	0.002	0.013	0.001	0.001	0.003
MAX	0.123	0.023	0.039	0.03	0.081	0.025	0.2144	0.093	0.213	0.199	0.28	0.0411
PERCENTAGE CHANGE FROM 1991-1993									+56.3	+272.7	+61.5	+76.8

* N - NAHAR (BEFORE CONFLUENCE)
D - DOWN STREAM OF ''J'' POINT
J - AT ''J'' POINT (AFTER CONFLUENCE)
U - UP STREAM OF ''J'' POINT

stream and 0.01258 mg/l at downstream in 1991 to 0.0425 mg/l, 0.0168mg/l and 0.0682 mg/l respectively in 1993, an increase of 272.72% at J-point 76.84% at upstream and 61.53% at downstream.

DISCUSSION

The river and estuarine water are being increasingly polluted on a global scale due to urbanization, industrialisation and recreational activities besides, the natural means. River water has proved to be the most ideal and convenient sink for sewage waste and industrial effluents. Mushrooming of industrial units, in the vicinity of rivers has become a common phenomenon world wide. Industrialisation of Baroda during the 1960's and 1970's was marked by establishment of industrial complexes in the north- western part of Baroda, involving Chhani, Nandesari, Bajwa, and Koyli on the banks of the river Mahi and its tributary the Mini. Unloading of Industrial effluents on a large scale into both Mini and Mahi posed serious problems to the populace and animal life in the downstream areas of river Mahi. This problem was further compounded by the construction of Kadana Dam in the year 1984, about approximately 160km. upstream of Mahi. This not only prevented flushing away of pollutants in the post monsoon lean months, but even aggravated the problem

Figure 19· Common effluent treatment plant at Nandesari.


WASTE WATER
TREATMENT PLANT
GIDC
NANDESARI
19

by the movement of the effluents further up stream during periods of sea ingress. As a remedial step, the commissioning of a common treatment plant (Fig- 19) and the 56 Km long effluent channel (Figs- 20a-i) for the purpose of transporting the effluent from the Nandesari Industrial complex to the Mahi estuary at the Gulf of Cambay was planned and executed in 1983. Since the commissioning of the treatment plant and the effluent channel, there have been frequent reports of breakdown of the treatment plant and even of its total non functioning as of now. Ironically, there have been no attempts to monitor and assess the impact of effluent channel on the water quality of the estuary. The present study is an exercise in this direction and has tried to assess the pollutant load of the effluent channel and also the water quality in the estuary, in the area where the channel effluent gets, mixed, as well as upstream and downstream of it.

The above mentioned aspect is well reflected by the values of various physico-chemical parameters of the effluent water before its confluence into the estuary at the Nahar point (Fig- 21) and, consequent effects on the water quality at the "J" point (confluence area) (Fig- 22) as well as at Sarod, upstream of "J" point (Fig- 23) and at Shiv temple, downstream of "J" point (Fig- 24) from 1991 to 1993. There

Figure 20a: Main pumping station cum collection wells at Dhanora for collecting effluents from industries

Figure 20b: Koyli collection center, part of the effluent from GSFC is brought here for outlet into the effluent channel.

Figure 20c: The collection wells at Koyli

20a


EFFLUENT CHANNEL PROJECT
COLLECTION STRUCTURE NO III
KOYALI
2.80 KM

20 b

20 C

Figure 20d: The peripheral cement channel through which the effluent from the tanks flows into the central distribution tank.

Figure 20e: The central distribution tank from a here the effluent is conducted into the effluent channel.

Figure 20f: The pipe above is the conducting structure for effluent into the koyli collection well and below is by pass channel to Mini.


20 d


20 e

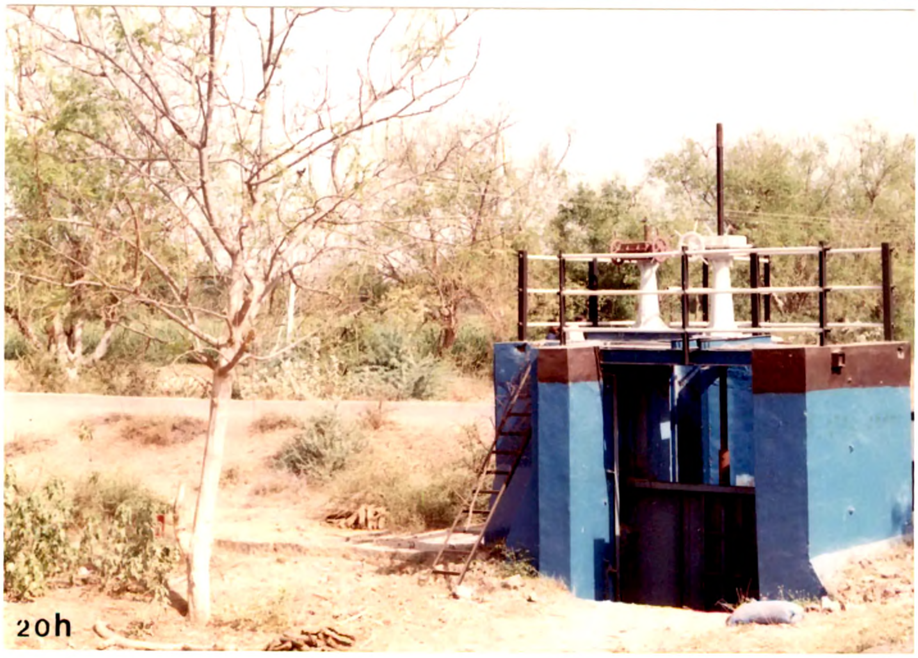

20 f

Figure 20g: The by-pass channel from Koyli coursing towards Mini river.

Figure 20h: Emergency by-pass sluice along the channel for conducting effluent into Mini river.

Figure 20i: The road towards "J" point with the channel on the left (arrow)


20g


20h


20i

Figure 21 A peep into the channel and the effluent.

Figure 22 The terminus of effluent channel (Nahar point in the present study) into the estuary at the Gulf of Cambay.

Figure 23 The "J" point at which channel effluent gets mixed with the estuarine water.

Figure 24 A view of the upstream area towards Mahi opening from the "J" point.

Figure 25 A view of the down stream area towards the sea from the "J" point Note the Shiv temple in the background (arrow)

23

24

25

are alarming trends of increase in TS, TDS, SS, COD, BOD, CI, SO_4, Hardness, Oil & grease, Phenol, and CN and decrease in pH, DO, Alkalinity, NH3-N, TKN, TC & FC respectively at all the three points from 1991 to 1993. Though there is subtle but definite alteration in the water quality downstream of "J" point, the magnitude of change is no doubt resisted and attenuated by the diluting influence of the sea water. However, the water quality at the "J" point and at Sarod, at the upstream point is the true reflection of the inefficient flushing capacity of the river and the increasing upward movement of the pollutants during times of tidal ingress (Barodawala-1990). It is estimated that during every tidal ingress, water is moved up the river mouth to as much as 70 km extending up to vasad, from where drinking water is supplied to parts of Baroda city collected by French wells (Barodawala-1990). The above work had suggested the imminent risk of contamination of drinking water by the pollutant load of the river. A cursory glance at table 3 and figures 1 and 2 shows that the pH of the effluent water decreased consistently during the three year period from 7.6 to 6.9, consequently the pH at the "J" point and Sarod fell from 7.5 to 7.0 and from 7.2 to 6.9 respectively. Even the downstream pH value of 7.7 in 1991 decreased to 7.3 in 1993. These changes in pH are paralled by decrease in alkalinity by 48% at Nahar by 41% at the "J" Point by 22.7% at downstream and by 12.67% at upstream. The increasing pollution load is well indicated by the increase in TS, inclusive of both TDS and SS, as well as COD and BOD values. Though many of the parameters of effluent channel water are much above the permissible levels according to international standards and World Health Organisation (WHO) standards, some of the parameters are much above the highly inflated permissible levels suggested by the Indian Pollution Control Board table 29-32 (Gujarat Pollution Control Board Guidelines, 1988). The DO content shows consistent decrease in channel water well below the value of 6 mg/l. Consequently the DO content of the estuary at the J-point, at up stream and at downstream decreased from 7.0 to 6.0 ppm. during 1991 to 1993.

Both the Cl^- and So_4 content showed significant increase, with the increase ranging from 84% and 77.96% respectively at Nahar, 74% and 116.92% at the J point, 73% and 104% at downstream and 221% and 122% at upstream respectively. Accordingly the hardness increased by 28% at J-point, by 24% at downstream and by 50% at up stream, while there was an actual increase of hardness of channel water by 155%. Though the oil and grease and phenol contents appeared to be within the prescribed limits, the increasing trend was of very high magnitude ranging from 57% at Nahar, 54% at the

TABLE 29: STANDARDS FOR DISPOSAL OF EFFLUENTS INTO BARODA EFFLUENT CHANNEL, BARODA *.

PARAMETER	MAXIMUM PERMISSIBLE CONCENTRATION	
Temperature	45° C	
pH	5.5 - 9.0	
Total Suspended solids (Flotable 3 mm, non-flotable 850 micron)	100	mg/l.
Total Dissolved solids	5000	"
B.O.D. (5 days 20° C)	100	"
Oil & Grease	10	"
Phenolic Compounds	1	"
Cyanide	0.2	"
Sulphide	1.0	"
Fluoride	10	"
Insecticides	Traces	
Arsenic	0.2	"
Barium	1.0	"
Cadmium	2.0	"
Copper	3.0	"
Chromium 6	0.1	"
Nickel	3.0	"
Lead	0.1	"
Mercury	0.01	"
Selemium	absent	
Zinc	10	"
Sulphate	1000	"
Chloride	1000	"
Radioactivity :		
Alpha emitters/uc/ml	10^{-7}	
Beta Emitters /uc/ml	10^{-6}	
Ammonical Nitrogen	100	mg/l.
C.O.D.	250	mg/l.

* Guidelines for Environmental Pollution Control, Gujarat - 1988

TABLE 30: STANDARDS FOR DISPOSAL OF EFFLUENTS INTO LAND SURFACE WATERS AND INTO OPEN LAND FOR PERLCOLATION

PARAMETER	MAXIMUM PERMISSIBLE CONCENTRATION
Temperature	$40^{o}C$
pH	5.5 - 9.0
Colour	100 units
Total Suspended solids	100 mg/1.
Oil & Grease	10 "
Biochemical Oxygen Demand (5 days at 20° C)	30 "
Chemical Oxygen Demand	100 "
Ammonical Nitrogen	50 "
Free Ammonia (as NH3)	5 "
Total Kjeldahl Nitrogen (asN)	100 "
Total Residual Chlorine	1 "
Phenolic Compounds	1 "
Total dissolved solids	2100 "
Cyanides (as CN)	0.2 "
Fluorides (Total as F)	1.5. "
Phosphates (as P)	5 "
Sulphides (as S)	2 "
Boron (as B) .	2 "
Arsenic (as AS)	0.2 "
Mercury (as Hg)	0.01 "
Lead (as Pb)	0.1 "
Cadmium (as Cd)	1.0 "
Hexavalent Chromium (as Cr^{+6})	0.1 "
Total Chromium (as Cr)	2 "
Copper (as Cu)	3 "
Zinc (as Zn)	0.05 "
Selenium (as Se)	3 "
Pesticides	Absent

* Guidelines for Environmental Pollution Control, Gujarat - 1988

TABLE 31: STANDARDS FOR DISPOSAL OF EFFLUENTS INTO LAND FOR IRRIGATION *

PARAMETER	MAXIMUM PERMISSIBLE CONCENTRATION	
Temperature	40oC	
pH	5.5 . 9.0	
Total Suspended solids	200	mg/l
Oil & Grease	10	"
Biochemical Oxygen Demand (5 days at 20 C)		
Total Dissolved solids	2100	"
Cyanides (as CN)	0.2	"
Boron (as B)	0.75	"
Arenic (as As)	0.1	"
Mercury (as Hg)	0.01	"
Hexavalent Chromium (as Cr +6)	0.1	"
Total Chromium (as Cr)	1.0	"
Copper (as Cu)	0.2	"
Zinc (as Zn)	2.0	"
Selenium (as Se)	0.02	"
Nickel (as Ni)	0.2	"
Pesticides	AbsenT	
Percent Sodium	60	

* Guidelines for Environmental Pollution Control, Gujarat - 1988

TABLE 32: STANDARDS FOR DISPOSAL OF EFFLUENTS INTO MARINE AND ESTUARINE ZONE *

PARAMETER	MAXIMUM PERMISSIBLE CONCENTRATION	
Temperature	45 C	
pH	5.5 - 9.0	
Colour	100 units	
Total Suspended solids	100	mg/1
Oil & Grease	20	"
Biochemical Oxygen Demand (5 days at 20^{o} C)	100	"
Chemical Oxygen Demand	250	"
Ammonical Nitrogen	50	"
Free Ammonia (as NH3)	5	"
Total Kjeldahl Nitrogen(as N)	100	"
Rotal Residual Chlorine	1	"
Phenolic Compunds	5	"
Cyanides (as CN)	0.2	"
Fluorides (Total as F)	10	"
Phosphates (as P)	5	"
Sulphyides (as S)	5	"
Arsenic (as As)	0.2	"
Mercury (as Hg)	0.01	"
Lead (asPb)	1.0	"
Cadmium (as Cd)	2.0	"
Hexavalent Chromium (as Cr+6)	2.0	"
Total Chromium (as Cr)	2	"
Copper (as Cu)	3	"
Zink (as Zn)	12	"
Selenium (as Se)	0.05	"
Nickel (as Ni)	5	"
Pesticides	Absent	

* Guidelines for Environmental Pollution Control, Gujarat - 1988

J-point, 72% at downstream and 39% at up stream with respect to oil and grease and by 306% at Nahar, 919% at the J-point and 167% at downstream and 5133% at upstream with respect to phenol content. The most serious increment was of SS, BOD, COD and CN, well surpassing the very high permissible levels in effluents to be discharged into the estuarine system set by the Gujarat Pollution Control Board guide lines. While the SS content exceeded the GPCB limit by 52% to 134% between 1991-to 1993, the COD value exceeded by 16% to 89% during the same period. The BOD content was higher by 44% in 1992 and by 88% in 1993, while the CN content crossed the fixed limit by 12% in 1993. In relation to this, all the above parameters showed continuously increasing trend at all the three estuarine points of study. The magnitude of increasing pollution load is revealed by the significant decrease in the TC and FC counts. Whereas the TC content decreased from 4067 MPN/100ml to 467 MPN/100ml at Nahar, from 1283 to 811 at the J-point, 11683 to 1250 at downstream and 7117 to 375 at up stream, the fecal coliform count decreased from 717 to 42 MPN/100ml at Nahar, 606 to 48 MPN/100ml at the J-point, 725 to 102 MPN/100ml at downstream and from 487 to 55 MPN/100ml at up stream.

The term heavy metal is a loose one and includes transition metals like chromium (Cr), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), cadmium (Cd), mercury (Hg), lead (Pb), arsenic (As), antimony (Sb) and bismuth (Bi). The most toxic metallic pollutants are mercury, lead, zinc and copper. In fact all metals are toxic at high concentrations but, some are highly toxic even at lower concentrations. Metals like Cu, Hg, Pb, Cd, Zn and Cr are very toxic (Wood-1974). Except for Cu and Zn, others are non-essential and toxic. Heavy metals occur naturally in the marine environment. In addition, these heavy metals enter the river and estuarine water by direct discharge via industrial and urban effluents, surface runoff and indirectly from aerial fallout (Schutz and Turekain, 1965). Metal contamination of estuarine and sea water is a global phenomenon and many workers have measured the concentrations of various metals in the Indian ocean, Arabian sea and the Bay of Bengal. Monitoring of Indian Ocean has shown concentrations of Cd, Cu, Fe and Ni to vary between 0.07 to 0.64 ug/l 0.2 to 0.63 ug/l; 0.46 to 12.0 ug/l and 0.3 to 1.1 ug/l respectively (Saager et. al, 1992) Monitoring of metal contaminants of Arabian sea has shown average (ug/l) concentration of Cu, Fe, Zn, Co and Ni to be 4.9, 20, 19.2, 2.2 and 3.2 respectively (Sengupta *et al.*, 1978). The relative concentrations of Cu, Fe, Zn, Ni and Co in the Bay of Bengal were found to be in the range of 22 to 37.2 ug/l, 6.2 to 131.5 ug/l, 2.4 to 20 ug/l, 1.2 to 1.7 ug/l and 1.0 to 7.9 ug/l respectively (Braganca and Sanzgiry, 1980). In comparison to these, the average metal concentration of the esturine water at the J-point in the Gulf of Cambay in 1993 was, Fe-38.75 ug/l, Ni-184.2 ug/l, Cu-2.388 ug/l, Zn-447 ug/l, Cd-26.52 ug/l, Pb 412 ug/l, Hg 42.5 ug/l and Cr 142.2 ug/l. Corresponding values for these metals at downstream (D) and at upstream (U) of J-point were, Fe- 18.3 and 721 ug/l, Ni- 75.5 and 296.1 ug/l, Cu- 193.2 and 202 ug/l, Zn 377.6 and 516.4 ug/l, Cd- 29.75 and 23.6 ug/l, Pb- 355.5 and 469.9 ug/l, Hg- 68.2 and 16.8 ug/l and Cr- 102.8 and 132.9 ug/l respectively. When compared with the reported values in the sea waters of India, these values are incomparably higher and denote the magnitude of unmindful and unchecked contamination of the Mahi estury by human activity. This is well corrborated by the levels of these metals in the effluent water at Nahar which were Fe-81.2 ug/l, Ni- 437.8 ug/l, Cu- 302.2 ug/l, Zn- 821.1 ug/l, Cd- 57.4 ug/l, Pb- 1.049 ug/l, Hg- 54.5 ug/l and Cr- 206.8 ug/l. The concentration of various metals measured annually from 1991 to 1993 indicates an alarming trend of increase ranging from a minimum of 27% for Cr to a maximum of 445.6% for Hg at downstream and from a minimun 76.8% for Hg to a maximum of 3883% for Fe in the upstream, (tables 21-28 and Fig- 16). This amply proves that unchecked discharge of effluent into the Mahi estuary is bound to have serious consequences in the foreseeable future. Cases of high metal concentration at upstream than even at the J-point for Fe, Ni, Pb and Zn suggest direct effluent discharge other than through the channel, probably through the Mini. The consequence of such high metal and organic pollutant contamination in the estuarine system is difficult to fathom as the physico-chemical behaviour, deep water processes, sedimentation processes and modes of degradation of the pollutants are not completely understood. It is necessary that caution should be exercised in the discharge of industrial effluents into the estuary or open sea due to following points.

1. The chemical behaviour of many pollutants and the way in which they may be altered or taken up by marine organisms in many cases are only partially understood.

2. It is not possible to accurately predict either the physical behaviour or the chemical or biological fate of a pollutant in the deep waters of ocean.

3. There is incomplete information regarding deep sea \`organisms' which might concentrate certain chemicals. Hence the need for waste disposal has to be properly weighed against the possible capacity of the ocean to accept waste of different kinds.

4. Many of the pollutants may become locked in the sediment and may lead to long term problems in an area.

Since the benthic population may be drastically altered. Alternatively, biochemical decomposition may lead to release of noxious materials such as sulfides or in special cases biologically hazardous forms.

5. The low rate of decomposition of organic pollutants in the sea would be particulary important in consideration of the quantities and materials which can be safely dumped into the estuary and sea water.

A close and careful consideration of the environs of the Mahi estuary at the Gulf of Cambay reveals, rapid erosion in the quality of estuarine flora and fauna. If caution is not exercised at this juncture it is likely to have serious socio-economic and medical problems to the populace and a complete anhilation of all biotic forms.