EFFECT OF WASTE DISPOSAL ON WATER QUALITY OF RIVER DAMODAR IN BIHAR : PHYSICO-CHEMICAL CHARACTERISTICS

M.P. SINHA

INTRODUCTION

The Damodar, one of the most polluted rivers of India is the master stream of Damodar Valley and in her course through the most productive and highly populated coalfield of the country with massive mushroom growth of industries, mostly coal-based, in its vicinity serves as the chief source of water for various human needs and activities of a large rural and urban population. Only at one place (at Jamadobha in Dhanbad) 9×10^9 gallons of water per day are being supplied for drinking from the river. Surprisingly enough on a river of such vital importance no systematic ecological work has been taken up so far to survey the state and extent of pollution and to study the ecology of the river as a whole. The surveys of aquatic systems both of lotic and lentic, not only provide data essential for the development of aquaculture and mangemental policies, but also furnish knowledge of individual waters, their characteristics as well as impact of catchment area (Vass *et al.*, 1977; Mishra and Yadav, 1978, Holmes and Whitton, 1981a; Holland *et al.*, 1983; Somashekhar *et al.*, 1984; Bhatt *et al.*, 1985). In contrast to lentic habitats lotic habitats accumulate naturally large varieties of dissolved matter as it passes through different types of soil and rocks on its course (Sinha and Sinha, 1986). From headwaters to mouth, the physical variables within a river system present a continuous gradient of physical as well as chemical conditions. This gradient elicits a series of responses within the constituent populations resulting into a continuum of biotic and abiotic adjustments along the length of the river (Cumminus, 1974; Vannote *et al.*, 1980; Holmes and Whitton, 1981b; Gregory, 1983). The issue of such responses becomes more important particularly when the river receives a huge amount of pollutants from the catchment area apart from the allochthonus materials. The objective of the present communication is to evaluate the impact of gradient of physico-chemical conditions along the course of river in the coalfield belt of Bihar as well as effects of pollutants load on water quality of the Damodar.

STUDY AREA

Geomorphologically the Damodar region is an old polycyclic area. The valley itself roughly coincides with a Permo-Carboniferous Rift Valley which has been re-excavated in the softer Gondwana sedimentaries surrounded by the harder ancient gneissic structures. The fault-line scarps bordering the valley provide marked breaks in the long profiles of the tributaries of the Damodar. On account of successive Tertiary and post-Tertiary rejuvenations there is a series of erosion surfaces in the catchment.

The Damodar, which rises in the eastern part of the Palamau district at an elevation of 609.60 M has a course of 540 km before its confluence with the Hooghly which it joins 40 km below Calcutta. About 289 km of her course fall in Bihar. The basin covers 20,792 sq. km of which 18,089 sq. kms are in Bihar. The average gradient of the river from the source to mouth is about 1.8 M per km and in Bihar, it is about 3.3 M per km. The floor of the valley slopes from about 518 M from the place of beginning to about 304 M up to near Ramgarh. From there it gradually falls to about 152 M in the middle of Dhanbad district.

The annual mean discharge of water in the Damoder has been estimated to be 12,210 M^3 at Sindri with the rate of flow 4,72,889 M^3 per km^2 and 387 M^3 per second (Rao 1979).

The valley receives an average rainfall of about 127 cm most of which is concentrated in the four months *i.e.*, June to September. Lying in the path of tropical cyclones originating in the Bay of Bengal or in the Far East, there are chances of storm rainfall *i.e.* high amount over a short period producing an average rainfall of 20 in with a run-off coefficient of 90 per cent and peak flows of as much as a million cusecs.

The concentration of fall of rain during the monsoon over gneissic rocks and sandstones and shales which are subject to marked weathering under a hot and humid climate causes much erosion over a relatively rugged surface loading the water of the river with great amount of sediments which choke the river downstream and cause floods in Bengal Minor floods occur every year and this sacred but untamed river well deserves the evil reputation it has acquired as the 'River of Sorrow' in West Bengal. The details of the study area have been shown in Fig. 9.1.

HUMAN ACTIVITY

The Damodar, in fact, in her course through highly populated and highly industrialized area of coalfield has become a repository of many types of wastes produced by various human activities like industrial, agricultural and domestic. The polluted plight of the river is enhanced with passing time due to continuous and uncontrolled discharges of toxic and hazardous effluents into it by over 46 industries located on its banks or in its vicinity particularly in Bokaro-Dhanbad areas of Bihar and Asansol-Durgapur regions of West Bengal. Apart from these, agricultural run-off from the catchment area and domestic wastes from thick population of this belt simply increase the extent of pollution of the river making the Damodar a constant agony from pollution view point.

INDUSTRIAL POLLUTION LOAD

About 161.2 KLD of wastes are discharged into the Damodar and its tributaries by as many as 29 industries in Bihar only.

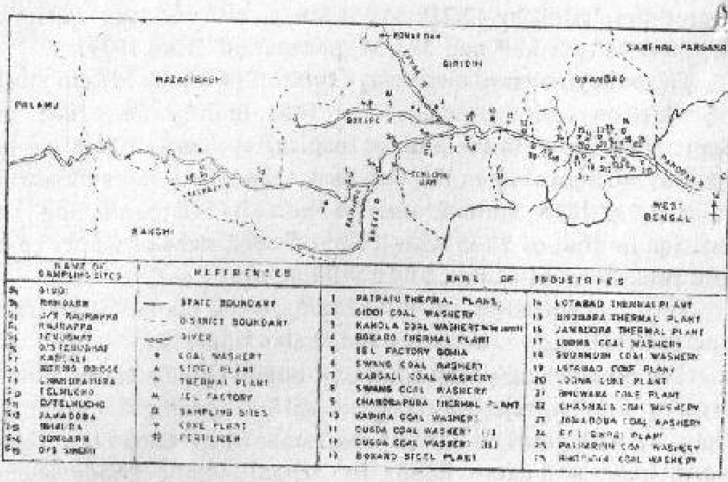

FIG. 9.1 : *Sampling sites and location of industries along the river*

Of these about 100.9 MLD of wastes are from 13 coal washeries and three thermal power plants. These constitute mainly of suspended fine grade of coal particles with concentrations ranging between 121.0 to 4500 ppm (average 2,293.75 ppm). Besides the river receives acidic wastes from Indian Explosive Ltd., at Gomia, phenol, oil and grease from Steel Plant of Bokaro and very high concentration of ammonia nitrogen (average 800 ppm), urea nitrogen (225 ppm), phosphate (40 ppm) and sulphate (1675 ppm) from Fertilizer Corporation of India (FCI) at Sindri.

Calculating the industrial pollution load of the river it is estimated that the river is receiving daily 364,864 tones (± 10 per cent) of suspended fine metallargical grade of coal particles from nearly 100.9 MLD of wastes from 13 coal washeries and thermal plants. Besides, 16 tons of ammonia-nitrogen, 4.5 tons of urea-nitrogen, 0.8 tons of phosphate and 33.5 tons of sulphate are discharged into the Damodar near FCI, Sindri.

Other than the above-mentioned industrial effluents there is a potential threat of water pollution due to coal mining activity in the Damodar Valley.

COAL MINING

From hydrographic view point the Damodar is the master stream of the valley where rapid drainage or overdrainage is the rule in the entire basin. The Damodar Valley in Bihar produces more than 50 per cent of coal in India and has more than 60 per cent of country's reserve of coal. Today, this coalfield is producing over 25 million tonnes of coal per annum and is likely to increase to three times of this production by A.D. 2000.

The most familiar water pollution problem due to mining results from drainage of mines and it becomes severe when the drainage is acidic. However, acid mine drainage is rarely encountered in this coalfield area (only Lakurka in Jharia and Swang in East Bokaro) while majority of the mines have water of alkaline (pH 7.5-9) nature. Interaction of minerals with natural undisturbed bed rock water due to coal mining results in chemical pollution of stream, even in the areas where acid is no problem (Curtis, 1972; Cairney and Frost, 1975). Table 9.1 shows the physico-chemical characteristics of drainage of coal mine.

Further, the methods of mining in this area both by underground through inclines and shafts and open-cast mines. Further production is being planned mostly by deep open-cast mines going down as deep as 300 metres coupled with rapid mechanisation. This will definitely imbalance and disturb the surface and underground hydrology of the area, affecting the availability of water.

The impact of mining also affects the water-table and groundwater pollution through the cracks produced due to subsidence movements because of underground mining and underground fires. As a result of the cracks the water bearing rock beds over the seam get disturbed causing lowering of water-table. Due to cracks the subsoil looses the water retaining capacity and through the cracks the unwanted material and other various pollutants including heavy metals reaches to the underground water and cause their polloution (EPA, 1973).

COAL WASHERIES

Out of 29 industries located in the vicinity of the Damodar

TABLE 9.1 : **Physico-chemical Characteristics of Coal Mine Effluents (Minimum-Maximum and Average)**

	Summer	Rainy	Winter	M	SD	CV	V
Temp. °C	26.3-32.5	25.2-32.3	27.5-29.5				
	28.5	30.1	27.3	28.86	2.678	9.25	7.12
pH	7.5-9.2	7.2-8.1	7.6-8.6				
	8.5	7.5	8	7.88	0.565	7.17	0.319
DO	5.4-7.4	5.4-7.8	5.3-7.8				
	6.42	6.55	6.35	6.44	0.787	12.23	0.60
Phenol. Alk.	21.2-38.2	30.5-69.5	28.7-52.1				
	26.08	51.10	38.50	38.55	15.06	39.06	226.80
MO Alk.	177.5-280.8	224.8-351.6	148.2-190.6				
	237.45	291.53	164.78	231.25	65.10	28.15	4238.04
Temp. Hard	102.6-170.7	124.2-185.3	99.0-183.5				
	124.25	165.78	158.20	149.41	35.81	23.26	1282.35
Perma. Hard	280.7-300.4	301.6-315.7	210.1-405.2				
	293.35	308.80	309.78	303.98	42.74	14.06	1826.70
Total Hard	400.7-450.8	425.8-496.1	209.1-688.6				
	417.60	474.58	467.98	453.38	69.46	15.32	4824.69

Dissolved Solids	213.8-515.2	466.2-598.2	240.2-558.2				
	423.77	544.8	424.7	464.42	121.13	26.08	1467.47
TSS	87.2-207.2	98.8-243.2	90.1-292.8				
	135.85	171.57	150.35	152.59	68.91	45.16	4748.58
COD	16.8-23.2	22.8-29.2	11.6-16.6				
	20.2	26.85	15.37	20.80	5.80	27.88	33.67
Chloride	49.9-88.6	24.8-46.8	21.3-50.2				
	65.05	34.68	40.40	46.71	19.15	40.99	366.72
Sulphate	48.1-117.2	75.6-101.2	90.2-143.2				
	80.15	88.98	115.45	94.85	25.13	26.49	631.51
Phosphate	111.2-192.7	82.1-110.6	87.2-152.8				
	151.82	99.27	128.82	126.64	36.84	29.09	1357.18
Iron	1.4-8.5	1.3-2.6	1.3-2.8				
	2.42	1.95	2.2	2.27	0.49	21.62	0.240

M = Annual mean; SD = Standard Deviation; CV = Coefficient of variation; V = Variance.
All parameters are in mg/l.

river in Bihar 13 are coal washeries. The coal washeries have problem in dewatering of coal fines which are generated during crushing and washing/benefication of coals. The effluents from these existing washeries carry a lot of fine coal (as pointed out above) in suspension and the water of the river at different regions often remains black due to the effluents from washeries.

The effluent characteristics from these washeries are almost the same and have been given in Table 9.2 and Table 9.5. Suspended solids and dissolved solids are far above the prescribed limits. Suspended solids concentration in the Damodar water reaches 3-4 gm/litre in certain areas whereas the IS-2490-1975 tolerance limits is only 100 mg/litre. Table 9.5 gives the picture of present state of different coal washeries from control measure of pollution view point. The physico-chemical characteristics of the effluents however changes to some extent if one put to settling ponds before discharge into the river. Table 9.3 shows the characteristics of coal washeries effluents which are allowed to settle in settling ponds.

COKE OVEN PLANTS

There are four coke oven plants located on the banks of the river Damodar and all are coupled with the by-product recovery facilities. Nearly one MLD effluent is discharged into the Damodar as shown in Table 9.5.

The wastes from coke oven plants has objectionable constituents such as ammonia, phenols, tarry oils, thiocyanates, sulphides, cyanides etc. The typical characteristics of effluents from coke oven plants are given in Table 9.4.

THERMAL POWER PLANTS

There exists six thermal power plants in the vicinity of the river. In addition to these FCI, Sindri and Bokaro Steel plant are having captive power plants. Water pollution problems in the Damodar river are mainly created from Chandrapura Bokaro and Pathratu Power Plants—which are based on pulverised coal firing system. In general, ash content of coal used in power plants varies between 20-40 per cent Pulverised coal firing suspends all the ash in the combustion gases and about 15 to 20

TABLE 9.2 : **A Characteristics of Effluent from Coal Washeries**

Physical appearance	Blackish brown to deep blakish
pH	7.1-7.8
Turbidity	10-25 JTU
Suspended solids	800-3500 mg/l
Dissolved solids	300-1500 mg/l
Hardness	130-450 mg/l
Alkalinity	10-90 mg/l
Chloride	10-40 mg/l

TABLE 9.3 : **Characteristics of Coal Washery Effluents which are allowed to settle in Settling Ponds**

Physical appearance	Blackish brown to deep blackish brown
pH	8.0-11.5
Turbidity	5-10 JTU
Suspended solids	30-40 mg/l
Alkalinity	70-200 mg/l

TABLE 9.4 : **Analysis of Effluents from Coke Oven Plants**

pH	7.5-8.5
Thiocyanate	50-100 mg/l
Total ammonia	300-350 mg/l
Sulphides	10-20 mg/l
Cyanides	10-50 mg/l
Phenols	900-1000 mg/l
Chlorides	4000-4500 mg/l
Thiosulphate	110-220 mg/l

per cent ash settles as a bottom ash in the boiler flues—which slurries up with water and piped to the Damodar river directly. Suspended solids concentration in the effluent varies between 3-4 grams/litre.

TABLE 9.5 : **Industrial Effluent Discharge and Effluent Quality observed (Year 1983-84) of Industries located on the Banks of River Damodar and on its Tributaries**

Sl. No.	Name of industry	Effluent discharge in MLD	Effluent quality observed (mean)			Remarks
			pH	Suspended solids mg/l	COD mg/l	
1	2	3	4	5	6	7
1.	Giddi Coal Washery	—	—	—	—	Effluent discharge diverted into Quarry.
2.	Pathratu Thermal Plant	—	7.2	3450	350	Effluents discharged into Nalkasi River which meets river Damodar.
3.	Kandla Coal Washery	—	—	—	—	Plant constructed recently.
4.	Kathara Coal Washery	9.0	8.0	3180	500	—
5.	Bokaro Thermal Plant	16.0	7.1	2540	60.0	—
6.	I.E.L., Gomia	2.70	7.9	170.0	320.0	$NH_3-N=34$; $SO_4=227$ mg/l Phenols=mg/l 0.9 mg/l
7.	Swang Coal Washery	1.0	7.1	2500	340	—
8.	Kargali Coal Washery	2.2	7.0	2050.0	280.0	—
9.	Bokaro Steel Plant	24.0	7.4	130.0	60.0	Phenols=0.08 mg/l, Oil grease =4.8 mg/l and cyanide
10.	Chandrapura Thermal Plant	34	8.0	3840	400.0	—
11.	Dugdha Coal Washery	4.0	8.0	600.0	400.0	—
12.	Barara Coal Washery	—	—	—	—	Effluent discharge directed into abandoned Quarry.

13.	Loyabad Coke Oven Plant	0.7	7.9	630.0	50.0	Oil and Grease 5.0 mg/l.
14.	Loyabad Power House	—	—	—	—	No industrial effluent discharge.
15.	Moonidih Coal Washery	—	—	—	—	—
16.	Barari Coke Oven Plant	—	—	—	—	Oil grease 14.0 mg/l.
17.	Lodhna Coke Oven Plant	—	7.7	350.0	410.0	—
18.	Lodhna Coal Washery	—	—	—	—	Effluent discharge diverted into abandened Quarry.
19.	Jamadoba Power House	—	—	—	—	No industrial effluent discharge.
20.	Jamadobe Coal Washery	1.80	708	1350.0	260.0	—
21.	Bhowra Coal Washery	—	—	—	—	No industrial effluent discharge.
22.	Bhowra Coke Oven Plant	0.090	8.2	520.0	100.0	Oil and grease 24.0 mg/l.
23.	Sudamdih Coal Washery	1.40	7.0	4500	—	—
24.	Patherdih Coal Washery	0.80	7.4	3640.0	345	—
25.	Chasnala Coal Washery	0.40	7.2	2100	540	—
26.	Bihar State Super Phosphate, Sindri	—	—	—	—	Plant closed
27.	F.C.I., Sindri	20.0	7.50	960	610	$F=14$, $NH_4-N=400$, Urea-N=200, PO_4
28.	P & D Catalyst Modernisation Plant, Sindri	—	6.8	150.0	—	—
29.	A.C.C., Sindri	—	—	—	—	No industrial effluent discharge.

ALLUCHTHONUS MATERIALS

The agricultural run off and domestic wastes from the terrestrial surroundings plays an important role in the ecology of running waters (Hynes, 1970; Cummins, 1974). As indicated by Fisher and Liken (1973) and Cummins (1974) for streams, a considerable amount of energy input is imported from terrestrial surroundings (*i.e.* it is allochthonus) with only a very small amount derived from stream photosynthesis.

The landscape of Damodar Valley in Bihar particularly is wooded steeps on the edges. The valley floor is marked by rice fields interrupted with forest clad masses of hills and hillocks. In such topographic condition the river naturally receives varieties of nutrient load in considerable amount along with agricultural run-off having fertilizers, and various biocides. However, a quantitative analysis of such import along with enrichment of water with nutrients by leaching of litter has not been done so far.

DOMESTIC WASTES

The urban domestic pollution load to the Damodar river is mainly attributed to the disposal of untreated domestic wastes. The physico-chemical characteristics of untreated domestic waste of Dhanbad area has been studied. Total urban BOD load in kilograms per day at the rate of 0.25/capita/day has been calculated. As per such calculation 3400 kg/day BOD load is added to the Damodar. The BOD load by rural domestic wastes has, however, not calculated. Due to such waste disposal BOD and total coliforms status of the river are found high.

OBSERVATIONS

The data recorded after the physico-chemical analysis of sample water following the standard methods (APAH, 1975; Trivedy and Goel, 1984), have been presented in Figs. 9.2 to 9.6. Water samples collected from 15 different sites, as shown and listed in Fig. 9.1, were collected monthly for eight months excepting rainy seasons and the values presented in figures are their mean. The mean values of different parameters longitudinally from site

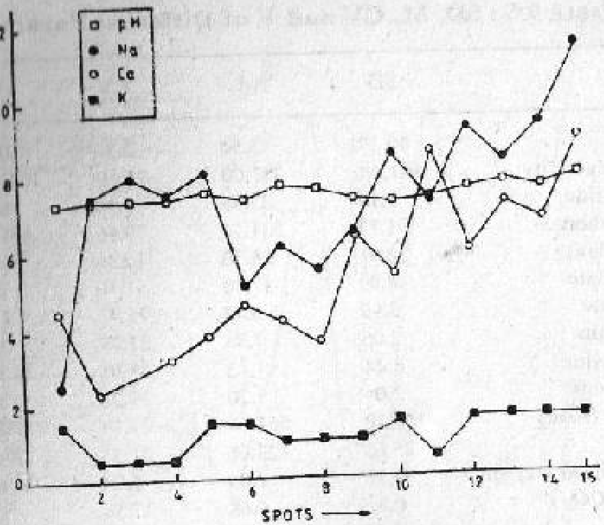

FIG. 9.2 : *Variation in pH, Na, Ca and K at different sites*

1 to 15, their standard deviations, coefficient of variations and variances have been included in Table 9.6, however, Table 9.9 presents the percentage increase in certain parameters at 15th site over 1st site to get the picture of salt formation and nutrients accumulation in the system.

Water was found alkaline throughout the period with pH ranging from 7.3 (at site 1) to 7.9 at site 15th (Fig. 9.2).

Maximum conductivity at 25°C was recorded 590 μS at 15th site while the minimum value was 270 μS at site 4 (Fig. 9.4). Chloride content was least at site 6 while bicarbonate at 7th (Fig. 9.3). The chloride content of water fluctuated from 18.6 mg/l to 43.8 mg/l while bicarbonate content 117 mg/l to 370.5 mg/l. Conductivity showed an increasing trend along the distance. The total alkalinity ranged 31.0 mg/l to 96.2 mg/ land did not show a trend of increase or decrease with distance along the length of the study area. Sulphate content was found six time increased from the first sampling site with nearly a definite trend of increase with the distance. The highest concentration in different parameters recorded at last sampling site could be attributed

TABLE 9.6 : **SD, M, CV and V of Different Parameters**

	SD	M	CV	V
pH	00.191	7.54	2.53	00.036
Conductivity	101.64	382.00	26.60	10330.69
Chloride	8.10	25.36	31.94	65.61
Bicarbonate	91.73	231.25	39.66	8414.39
Alkalinity	22.91	56.76	40.36	524.86
Sulphate	8.89	17.40	51.10	79.03
Nitrate	3.99	5.48	75.42	17.08
Sodium	2.06	7.38	27.79	4.24
Potassium	0.44	1.13	38.93	0.16
Calcium	2.04	5.20	39.23	4.16
Total Solids	159.30	551.58	29.89	27188.71
TSS	25.63	123.08	21.55	704 03
Dissolved Oxygen	0.35	7.05	5.24	0.13
Free CO_2	0.82	4.68	17.58	0.67
BOD	1.08	3.78	28.07	1.12
COD	1.28	5.75	22.95	1.74
Coliforms MPN	3.99	5.48	75.42	17.08

SD=Standard Deviation; M=Mean; CV=Co-efficient of Variation; V=Variance

to the effluents effect from fertilizer industry. Sodium content varied from 2.5 mg/l to 11.3 mg/l while variation in potassium concentration was very narrow (Fig. 9.2).

One of the most serious threat to water quality of the river is due to total solids. The high concentration of total solids ranging from 305.3 mg/l to 755 mg/l was observed which inturn causes many other limnobiotic problems damaging the system. The solids actually are fine coal particles coming with coal washeries effluents. A low range of fluctuation in dissolved oxygen content was recorded, minimum being 6.7 mg/l and maximum 7.5 mg/l (Fig. 9.5) multiple sources of pollutants at various points, there was no positive impact of self-purifying ability on water quality. High suspended solids, high salt concentration and various toxic pollutants like cyanides have destroyed the usual biota. Colour of water was observed mostly black, planktonic as well as benthic and fish communities are nearly nil.

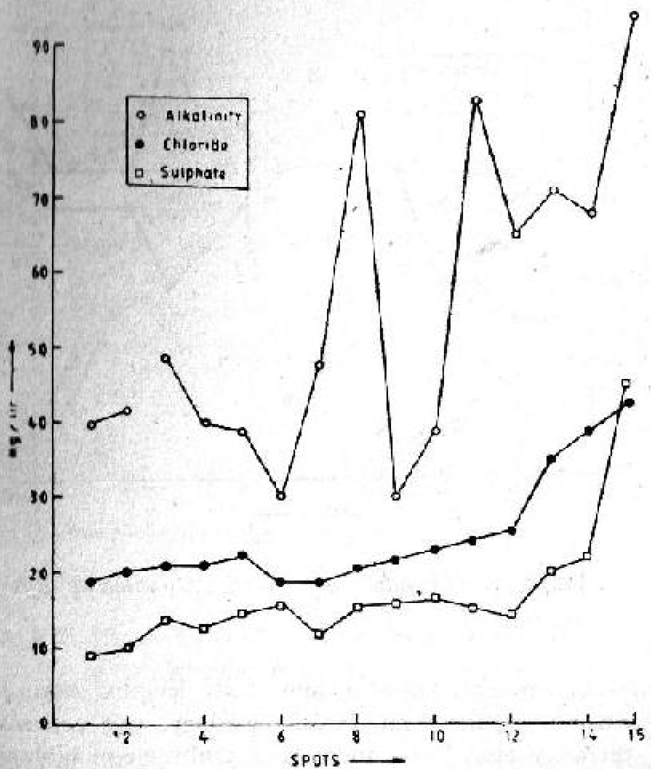

FIG. 9.3 : *Variation in SO_4, Cl and alkalinity at different sites*

Free CO_2 was recorded at every site probably as an effect of microbial activity over organic wastes. BOD was found high, never below 2.6 mg/l and going up to 5.9 mg/l. COD values were higher than BOD values probably due to high inorganic industrial waste in the system (Fig. 9.5). Correlated with high BOD values high NPN of coliforms/100 ml was observed as shown in Fig. 9.6.

DISCUSSION

In comparison to stagnant waters, flowing water is a particularly complex situation, for rivers alter not only through cyclic,

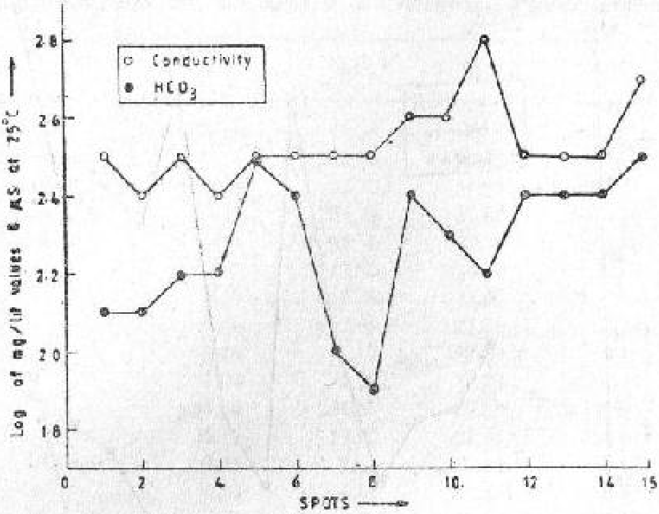

FIG. 9.4 : *Variation in conductivity and* HCO_3 *value at different sites.*

seasonal progressions, but also along their lengths, according to their depth, gradient, rate of flow, geology, salt concentration, turbidity etc. Thus, there is a multitude of biological habitats. Stadecek (1972, 1973) has described the longitudinal changes occurring in streams as successions. He proposed that the normal series of changes occurring in downstream was a primary succession proceeding through a number of serial states to a naturally eutrophic climax stage. But in any event the longitudinal changes occurring down a river are not succession. The term succession refers to a change in time rather than a change in space (Odum, 1971). Further once the stream community has adapted to the pressure of the effluents the system is held in a steady state (Wuhrmann, 1972) which could probably be best described as a dis-climax (Campbell, 1978). The present study is in accordance with the above findings as the concentration of salt increases along the flow affecting adversely the biota, thereby decreasing productivity.

Pollutants introduced into rivers are naturally carried downstream but, after initial mixing, do not become further diluted

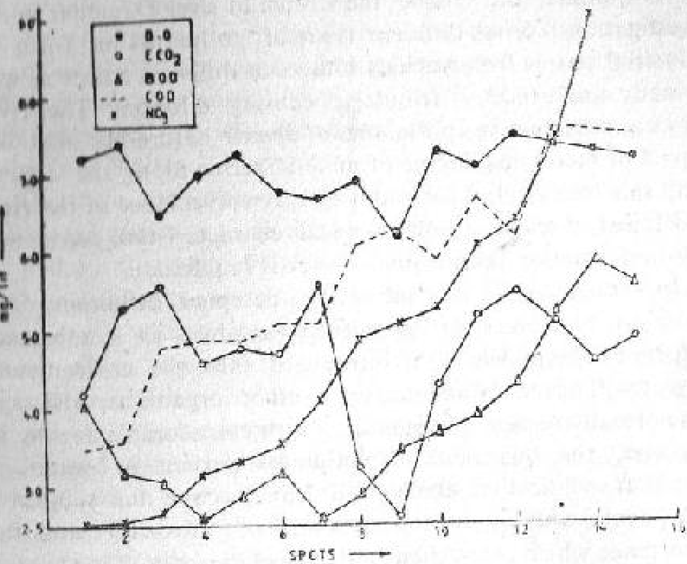

FIG. 9.5 : *Variation in DO, Free CO_2, BOD, COD and NO_3 values at different sites.*

except because of confluence with other water source. Removal of pollutants than depends on their biological degradation or deposition. The general picture of introduction of a pollutant into a river is shown in Fig. 9.7. In the streams polluted at a single point, as in most theoretical models (Bartsch, 1948; Bartsch and Ingram, 1959; Klein, 1959; Hynes, 1960; Curtis and Horrington, 1970; Campbell, 1978) it is simple to decide on the relative degree of pollution at points downstream ; the point just below the source is most polluted, and subsequent points are progressively less polluted. In fact such situations are rare, sources of pollution generally being multiple and frequently diffuse as has been observed in the present investigation. Under such circumstances the investigator then is confronted with the problem of evaluating pollution on the basis of conflicting data. Mostly such evaluations have been made, they are subjective ; however, at least some attempts have been made towards increasing the objectivity of these evaluations (Prati, *et al.*, 1971).

As pointed out above the stretch of river Damodar under investigation receives different types of pollutants in form of industrial wastes from various sources at different points as well as many confluences of tributaries causing dilution. The river thus not only receives pollutants of diverse nature but also has impact of increasing degree of mineralization along the course. With this background for water quality surveillance of the river a detailed discussion on chemical characteristics containing more information than a single index is required.

In fact there is no universally accepted definition of a pollutant, but it can be conveniently explained as a substance or form of energy which, if introduced into the environment, may or will adversely affect man or other organisms. Although it is normally possible to measure, with considerable degree of precision, the quantities of pollutants present in water, a definition such as that above still leaves scope for subjective assessment, notably in the meaning of 'adversely' and the importance which is attached to degree of diversity. The varieties of pollutants being discharged into the river Damodar with effluents from industries as mentioned above are well-known to affect man and biota of the river as a whole. Further, whether or not particular substance is a pollutant depends on its nature, its concentration in the effluent, the total load discharged, the nature of the receiving water and its capacity to absorb the waste loading imposed upon it. Thus, in the appropriate circumstances, even distilled water can be a pollutant. Thus the sign of accumulation or increase in concentration of pollutants is indicative of higher load of discharges into the system than the carrying capacity of the system as has been observed in the present study.

The higher concentration of various chemical parameters during the investigation in downstream of the river depicts pollutant load well above the threshold limit of the self-purifying capacity of the river and hence the nutrients of the water body are the pollutants.

The higher concentrations of nutrients, particularly nitrogen and phosphorus are naturally to be expected in polluted waters (Vollenweider, 1968; Munawar, 1970). Ganpati (1960) pointed out that the tropical waters, particularly unpolluted ones are deficient in nitrates. Reid (1961) also found that the world average of nitrates in unpolluted fresh waters is 0.30 mg/l. In Damodar water at every sampling site the concentration of nitrate is relatively much higher than this limit. The abnormally high content at 15th site is probably due to waste from fertilizer industry at Sindri.

The high amounts of chloride in fresh waters have been considered generally to be due to pollution. Thresh *et al.* (1944) pointed out that high chloride concentrations are indicators of large amount of organic matter in the water. Chloride content also increase with the degree of eutrophication (Goel *et al*, 1980; Sinha, 1986). Ownbey and Kee (1976) observed three-fold increase in chlorides in lake Erie and accounted for 70 per cent of the total increase mainly due to industrial effluents, road salting and municipal wastes. High concentration of chloride content and an increase by 132.97 per cent within the study area reflects the increasing pollution along the river flow and also as an effect of waste disposal into the river.

Due to high input of organic matter, Ruttner (1953) and Vomos (1964) have reported high sulphate and its reduction. Steiver (1967) has also reported that the sulphate very fastly reduces to hydrogensulphide under high organic pollution and depleted oxygen condition.

According to Abdullah and Royle (1972), EPA (1973) Foehrenbach (1973) fresh waters if contain high amount of soluble salts their character is altered and hence productivity is affected.

The alkalinity of water varies in different zones. This is probably due to the geology of the course of flow of the river and secondly also by effluents. Generally hardness of water less than 50-150 ppm is moderately hard, 150 to 300 ppm hard and over 300 ppm considered as very hard. The water of study area up to site 3 is moderately hard and from there up to site 9 its soft and again hardness increases being highest at site 15.

Unlike lake systems, river water quality cannot be characterized by the concentrations of nutrients (Wong *et al.*, 1979). Dissolved oxygen content, which plays a vital role in supporting aquatic life in running waters, is susceptible to slight environmental changes. Oxygen depletion often results during times of

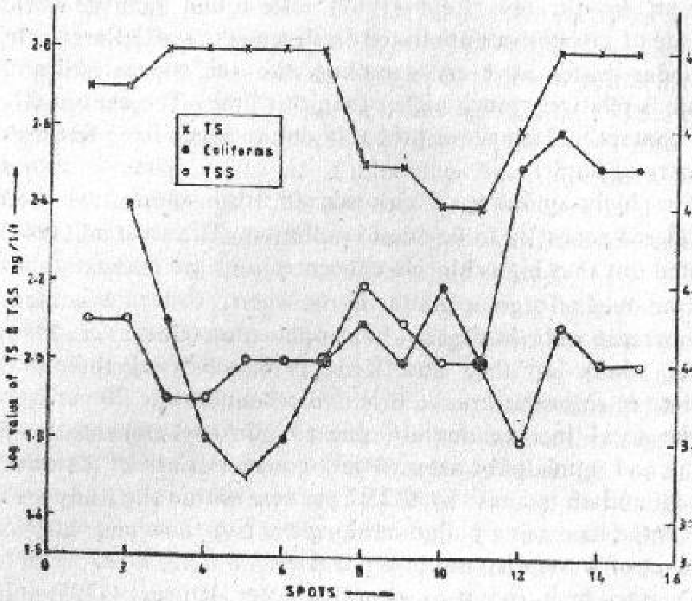

FIG. 9.6 : *Variation in TS, TSS and Coliforms at different sites.*

high community respiration. For this reason, dissolved oxygen has been extensively used as parameters delineating water quality (Wong *et al.*, 1979). Also, because the solubility of dissolved oxygen is temperature dependent, the acceptable dissolved oxygen levels are generally related to seasonal water temperature (Table 9.7; EPA, 1973). Many chemical and physical reactions in water may affect the dissolved oxygen content, but the per cent saturation would usually remain close to 100 per cent in the absence of any biological activity (Wong *et al.*, 1979). In addition to these, in shallow, turbulent streams dissolved oxygen levels are normally at 100 per cent saturation or greater (Hynes, 1970). Minckley (1963) has recorded a maximum level of 191 per cent of oxygen saturation in polluted running water. During the present investigation the percentage of oxygen saturation being always more than 100 per cent and dissolved oxygen never going below 6.3 mg/l, as well as due to high pollution load the system being devoid of usual biotic community confirms the above findings and also depicts that the

TABLE 9.7 : Minimum Dissolved Oxygen Concentrations recommended for the Protection of Aquatic Life (EPA, 1973)

Temp. (°C)	O_2 at 100 per cent saturation mg/l	Min. O_2 for protection of aquatic life	
		Conc. mg/l	Per cent saturation
36	7	5.8	85
27.5	8	5.8	73
21.0	9	6.2	70
16.0	10	6.5	66
7.7	12	6.8	57
1.5	14	6.8	48

amplitude of dissolved oxygen in lotic aquatic systems is, in fact, mainly due to biotic functions. Such phenomenon is best illustrated by the equations of oxygen balance in streams put forward by O'Connell and Thomas (1965) and Owens *et al.* (1969) shown in the Table 9.8. Probably due to the reasons explained above in this study the minimum fluctuation in dissolved oxygen has been noticed. The effluents from coal-

TABLE 9.8 : The Dissolved Oxygen Model

1. O'Connell and Thomas, 1965

$$Q=(P-R)+K_2D-K_1L$$

Q = rate of change of oxygen per unit surface area of reach (g/m²/h)

$P-R$ = net photosyntheses *minus* respiration (mg/l/h)

D = oxygen deficit concentration (mg/l)

L = ultimate BOD concentration (mg/l)

K_1 = deoxygenation rate constant (h)

K_2 = reaeration rate constant (h)

2. Owens, Knowles and Clark 1969

$$Q=F/S\,(C_2-C_1)-P_b+P_p-R_p-R_b-R_m+D$$

F = flow (m³/h)

S = surface area of the reach (m²)

$C_1\&_2$ = concentration of oxygen (mg/l)

$P_{b,p}$ = photosynthetic oxygen production by attached plants and phytoplankton (g/m²/h)

$R_{p,b,m}$ = oxygen consumption of bottom deposits, attached plants and suspended organisms (g/m²/h)

D = Oxygen contributed by diffusion through the water surface (g/m²/h).

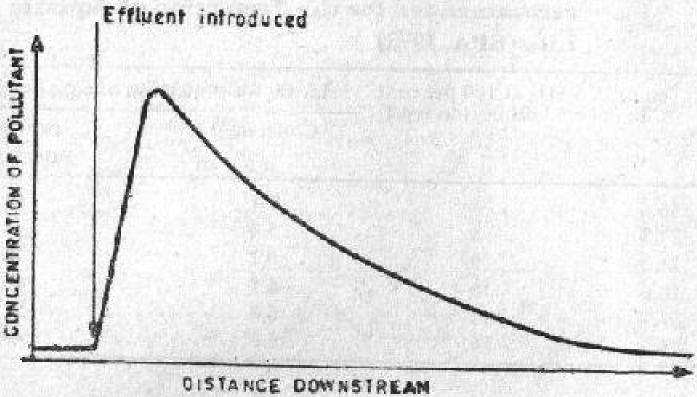

FIG. 9.7 : *Generalised picture of the introduction of a pollutant to a river. After a short period of mixing, by which the whole volume of water reaches peak pollutant concentration, the level of pollution gradually decreases.*

based industries and coal particle containing wastes have been described as oxygen depleting agents (Sinha and Sinha, 1986). Even after their abundance in the system a healthy condition observed from oxygen view point is indicative of the fact that not the physico-chemical but biological and rheological factors govern the oxygen level in lotic systems.

The minimum quanities of dissolved oxygen required in water depend up on the individual organisms. Most of the fishes require at least 5 mg/l dissolved oxygen for at least 16 hours/day, and never less than 3 mg/l for 8 hours. Most natural waters contain 8-10 mg/l oxygen depletion, mainly other than respiration of biota, is caused by high organic load hence by micro-organisms such as bacteria (EPA, 1973; Rodgi & Nimbargi, 1978).

The water of river Damodar in the the whole study area has been found alkaline on the basis of pH. This indicates that the decomposition of organic matter received by the river either as human and industrial waste or as allachthonus materials from the catchment area have not supressed the pH. Except only a

TABLE 9.9 : **Percentage Increase in Different Parameters at last Sampling Site in Relation to the First**

pH	8.2 %
Conductivity	78.78%
Chloride	132.97%
Bicarbonate	189.22%
Akalinity	139.30%
Sulphate	441.86%
Nitrate	695.65%
Sodium	352.00%
Potassium	6.6 %
Calcium	97.77%
Total Solids	32.50%
TSS	(—) 14.87%
Dissolved Oxygen	1.38%
Free CO_2	16.66%
BOD	36.58%
COD	114.28%
Coliforms MPN	28.57%

few industrial effluents like explosive factory at Gomia majority of factories discharge alkaline effluents which in turn keep the nature of river water alkaline. Hutchinson *et al.* (1929) and Roy (1955) have asserted that the high pH is associated with high photosynthetic activity. Atkins and Harris (1924) have reported high pH values favourable to dissolved oxygen saturation.

The transport by flowing water of solid particles in suspension is a natural phenomenon, aggravated in the case of mining by the creation of disturbed areas of land susceptible to erosion. A wide variety of inert inorganic materials arises from mining, together with a relatively minor contribution from organic solids. If, in the latter category, coal is included, the organic fraction becomes of great importance. Coal is a particular discolourant, and its phenolic content can also be damaging (Oschwald, 1972; Stall, 1972; Clausen, 1973; Prosser, 1974).

A high amount of TSS concentration found during study is infact due to discharges from coal washeries and other industries with coal particle as the chief component. The TSS concentration, being very high, has been observed not only to impart back colour to water but also to reduce the transparency to nearly nil. According to Clausen (1973) such suspended solids interfere with self-purification of water by diminishing light penetration and hence photosynthetic activity and damage fisheries by silting over food organisms. Probably due to this reason the planktonic and benthic populations have been highly destroyed in the river apart from aesthetic nuisance.

The presence of free CO_2 content at every site is an effect of microbial activity of coverting organic waste, into water and CO_2 because the respiratory activity is nearly nil due to absence of usual biota.

The increase in BOD and bacterial level has been considered indicative of increasing pollution (Rao, 1976; Campbell, 1978; Mahadevan & Krishnaswamy, 1984) a condition similar to the present observation. The high concentration of coliform bacteria is probably a result of sewage discharge and faecal contamination making the river water not fit for direct human use.

The COD value always record higher than BOD values clearly indicates that the non-biodergadable oxygen-demanding pollutants are present in the water which come into the system as industrial discharges.

SUMMARY

The main impurities in river Damodar is due to coal-based industries along the river bank. Out of 29 industries located on the bank of river Damodar, 13 are coal washeries. These coal washeries units contribute high suspended solids (1 to 5 g/l) to river Damodar. The thermal power plant and coke oven plants contribute to a high level of pollutant load to the river.

In summer season the river water becomes a drain for carrying industrial effluents discharge. The feasibility to divert mine pit water discharge to river Damodar may be considered to maintain river flow specially in summer season.

On the basis of the present study it has been found that at no point the quality of water is at the desired level and quality management is needed every where. The high degree of salt built-up and its accumulation as shown in the Table 9.9 further underlines the need of detailed ecological study of the river.

Author's address : *Department of Zoology, R.S. More College, Govindpur, Dhanbad, Bihar.*

REFERENCES

Abdullah, M.I. and Royle, L.G., 1972, "Heavy metal content of some rivers and lakes in Wales", *Nature*, 288 ; 329-30.

A.P.H.A., 1976, *Standard Methods for the Examination of Water and Waste water*. American Public Health Association, New York.

Bartsch, A.F., 1948, "Biological aspects of stream pollution", *Sewage Works J.*, 20 : 292-302.

Bartsch, A. F. and Ingram, W. M., 1959, "Stream life and the pollution environment", *Public Works*, 90 : 104-110.

Bartsch, A.F. and Ingram, W. M., 1966, "Biological analysis of water pollution in North America", *Verh. Int. Verein, Theor. Angew. Limnol.*, 16 : 786-800.

Bhatt, S.D., Bisht, Y. and Negi U., 1985, "Hydrology and phytoplankton populations in River Kosi of Western Himalaya (U.P.)", *Indian. J. Ecol.*, 12 (1) : 141-146.

Cairney, T. and Frost, R.C., 1975, "A case study of mine water quality deterioration, Mainsforth Colliery, County Durham", *J. Hydrology*, 25 : 275-293.

Campbell, I.C., 1978, "A biological investigation of an organically polluted urban stream in Victoria", *Aust. Mar. Freshwater Res.*, 29 : 275-91.

Clausen, L.H., 1973, "Ecological aspects of slimes dams construction", *J. Sth African Inst. Min. Metall.*, 74 (5) : 178-83.

Cummins, K.W., 1974, "Structure and function of streem ecosystems", *Bioscience.*, 24(11) : 631-641.

Curtis, W.R., 1972, Chemical changes in stream flow following surface mining in Eastern Kentucky. *4th Symp. Coal Mine Dran. Research. Mellon Inst. Penn. Proc.*, 19-31.

Curtis, E.J.C. and Harrington, D.W., 1970, "Pollution related structural and functional changes in aquatic communities with emphasis on freshwater algae and protozoa", *Proc. Acad. Nat. Sci. Philadelphia*, 124 : 79-127.

EPA, 1973, *Groundwater pollution from surface excavations*, U.S. Environmental Protection Agency, Washington, D. C.

EPA, 1973, *Processes, procedures and methods to control pollution from mining activities*, U.S. Environmental Protection Agency, Washington, D. C.

EPA, 1973, *Water Quality Criteria*, Vol. 1, p. 98. National Academey of Sciences, Washington, D.C.

FAO, 1973, "European Inland Fisheries Advisory Commission, Water quality criteria for European freshwater fish" : *Report on Dissolved Oxygen and Inland Fisheries, FAO, EIFAC Tech. Paper 19*, Rome.

Fisher, S.G. and Likens, G.E., 1978, "Energy flow in Bear Brook, New Hampshire : An investigative approach to stream ecosystem metabolism", *Ecol. Monogr.*, 43 : 421-439.

Odum, E.P., 1971, *Fundamentals of Ecology*, 3rd Edn. W. B. Saunders and Co., New York.

Oschwald, W.R., 1972, "Sediment water interaction", *J. Environ. Quality*, 1 (4) : 353-359.

Owens, M., Knowles, G. and Clark, A., 1969, "The prediction of the distribution of dissolved oxygen in rivers. Advances in Water Pollution Research", *Proceedings of 4th International Conference in Prague*, Pergammon Press, 125-146.

Ownbey, C.R. and Kee, D.A. 1967, "Chlorides in lake Erie", *Proc. Conf. Great Lakes Res.*, 10 : 382-389.

Prati, L., Pavanello, R. and Pesarin, F., 1977, "Assessment of surface water quality by a single index of pollution", *Water Res.*, 5 : 741-751.

Prosser, M.J., 1974, *Plant Discharge to the River Boyne*, British Hydromechanics Research Association, report of research, 1238, BHRA, Bedford.

Rao, S.S., 1976, "Observation on bacteriological conditions in the Upper Great Lakes" (1968-1975) In : *Scientific series No. 64*, Inland Waters Directorate, CCIW Branch, Burlington, Ontario.

Reid, G.K., 1961, *Ecology of Inland Waters and Estuaries*, Reinhold Publ. Corp., New York.

Rodgi, S.S. and Nimbargi, P.M., 1978, "Sewage pollution and fish life—A review", *J. of the Karnataka University : Science*, XXIII : 92-115.

Roy, H., 1955, "Plankton ecology of river Hooghli (West Bengal)", *Ecology*, 36 : 169-175.

Ruttner, F., 1953, *Fundamentals of Limnology*, University of Toranto Press, Toranto.

Somashekar, R.K., Swamy, S.N.R. and Brekal, G.D., 1984, "Ecological study on the algae of waste waters of a textile mill near Nanjangad, Karnataka", *Comp. Physiol. Ecol.*, 9 : 75-79.

Sinha, M.P., 1986, "Limnobiotic study on trophic status of a polluted freshwater reservoir of coalfield area", *Poll. Res.*, 5 (1) : 13-17.

Sinha, M. P. and Sinha, K., 1987, "Ecological studies on characterization of coal mine effluents for pollution control", *J. Ind. Poll. Cont.*, (in press).

Sinha, M.P. and Sinha, K., 1986, *Salt build up in a polluted tropical river*, Abs. No. C-21. National Seminar on Role of Applied Sciences in Mineral Industries. A. Environmental pollution section. Organised by Indian School of Mines, Dhanbad.

Sladecek, V., 1972, "Saprobic successions", *Verh. Int. Verein. Theor. Angew. Limnal*, 18 : 896-902.

Sladecek, V., 1973, "System of water quality from biological point of view", *Ergeb. Limnol. Heft.*, 7.

Stall, J.B., 1972, "Effects of sediments on water quality", *J. Environ. Quality*, 1(4) : 353-359.

Steiver, M., 1967, "The sulfer cycle in lake waters during thermal stratification", *Geochim. Cosmochim. Acta.*, 31 : 2151-2167.

Foehrenbach, J., 1973, "Eutrophication", *J. Water Poll. Control Fed.*, 45 (6) : 1237-1246.

Ganapati, S.V., 1960, "Ecology of tropical waters", p. 204-218, In : (D. Raghavan & P. Kachroo (Eds.) *Proc. Symposium on Algology.* I.C.M.R., New Delhi, India.

Goel, P.K., Gopal, B. and Trivedi, R.K., 1980, "Impact of sewage on freshwater ecosystems. II. Physico-Chemical characteristics of water and their seasonal changes", *Int. J. Ecol. Environ. Sci.*, 6 : 97-116.

Gregory, S.V. 1983, Plant—herbivore interactions in stream ecosystems. In : *Stream Ecology* edited by J. R. Barnes and G. W. Minshall. Plenum Publishing Corporation, 157-189.

Holden, J.M. and Green, J., 1960, "Hydrology and phytoplankton of the river Sokoto", *J. Anim. Ecol.*, 29 : 65-84.

Holmes, N.T.H. and Whitton, B.A., 1981a, "Phytobenthos of the river Tees and its tributaries", *Freshwater. Biol.*, 11 : 139-168.

Holmes, N.T.H. and Whitton, B.A., 1981b. Phytoplankton of four rivers, the Tyne, Wear, Tees and Swale," *Hydrobiologia*, 80 : 111-127

Hutchinson, A.H., Luces, S.C. and McPhail, M., 1929., "Seasonal variations in the chemical and physical properties of the culture of the strait of Georgia in relation to phytoplankton. *Trans. Roy. Soc., Canada*, 3 : 177-183.

Hutchinson, G.E., 1957, *A Treatise on Limnology*, Vol. I, John Wiley, New York.

Hynes, H.B.N., 1960, *The Biology of Polluted Waters*, Liverpool University Press, Liverpool.

Hynes, H.B.N., 1961, *The use of biology in the study of water Pollution chem. Ind.* (London), 435-436.

Hynes, H.B.N., 1970, *The Ecology of Running Waters*, Liverpool University Press, Liverpool.

Klein, L., 1959, *River Pollution*, Vols I-III, Butterworths, London.

Mahadevan, A., and Krishnaswamy, S., 1984, "Chironomid Larval population size—An index of pollution in river Vaigai", *Poll. Res.*, 3 (1) : 35-38.

Minkley, W.L., 1963, "The ecology of a spring stream, Doe Run, Meade County, Kentucky", *Wildl. Monogr.*, 11 : 124.

Mishra, G.P. and Yadav, A.K., 1978, "Comparative study of physico-chemical characteristics of river and lake waters in Central India", *Hydrobiologia*, 59 : 275-278.

Munawar, M., 1970, "Limnological studies on freshwater ponds of Hyderabad, India. II. The biocenose, distribution of unicellular and colonial phytoplankton in polluted and unpolluted environments", *Hydrobiologia*, 36(1) : 105-128.

O'Connell, R.L. and Thomas, N.A., 1965, "Growth and mineral accumulation of submersed vescular hydrophytes in pleioeutrophic environs", *Inr. Wat. Res. Mich. St. Univ. Tech. Rep.*, No. 26 : 33.

Thresh, J.C., Suckling, E.V. and Beals, J.E., 1944, *The examination of water and water supplies*, London.

Trivedi, R.K. and Goel, P.K., 1984, *Chemical and Biological Methods for Water Pollution Studies*, Environmental Publications, Karad, India.

Vass, K.K., Raina, H.S., Zutshi, D.P. and Khan, M.A., 1977, "Hydrological studies of river Jhelum", *Geobios*, 4 : 238-242.

Vannote, R.L., Minshall, G.W., Cummins, K.W., Sedell, J.R. and Cushing, C.E., 1980, "The river continuum concept", *Can. J. Fish. Aquat. Sci.*, 37 : 130-137.

Vollenweider, R.A., 1968, *Scientific Fundamentals of the Eutrophication of Lakes and Flowing Waters with Special Reference to Nitrogen and Phosphorus as Factors of Eutrophication*, O.E.C.D., Paris, Report No. DAS/CSI/68-27.

Welch, P.S., 1948, *Limnological Methods*, The Blakiston Div., Philadelphia.

Welch, P.S., 1952, *Limnology*, McGraw-Hill Co., Inc., New York.

Wong, S.L., Clark, B. and Koseiuw, R. F., 1979, "An examination of the effects of nutrients on the water quality of shallow rivers", *Hydrobiologia*, 63 (3) : 231-239.

Wuhrmann, K., 1972, "Stream purification". In R. Mitchell, (ed.) *Water Pollution Microbiology*, Wiley Inter-Science, New York.