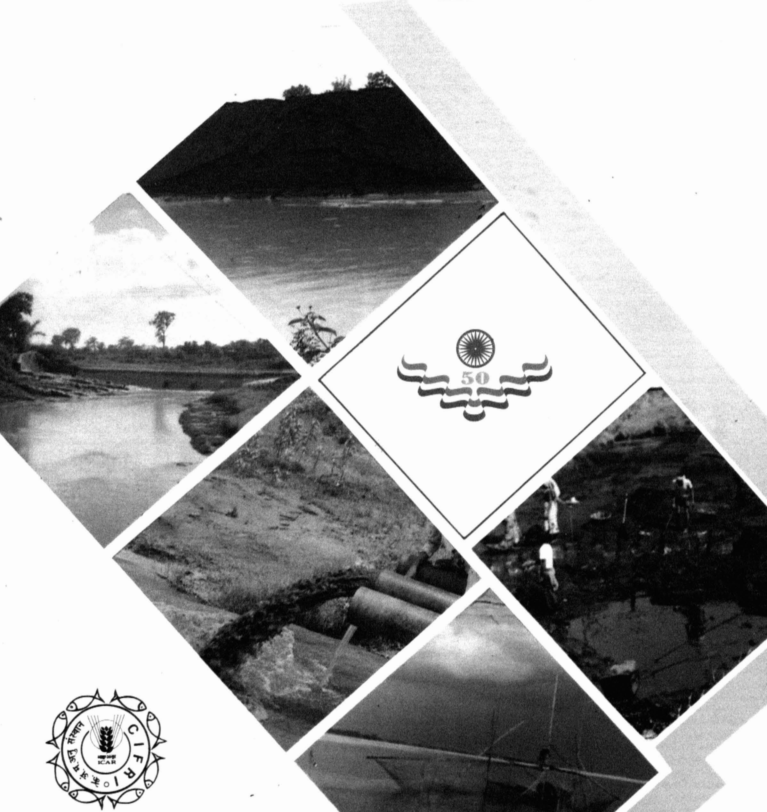
THE RIVER DAMODAR AND ITS ENVIRONMENT



CENTRAL INLAND CAPTURE FISHERIES RESEARCH INSTITUTE BARRACKPORE

The River Damodar and its Environment

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FOREWORD

In India the different river systems from times immemorial have served as source of livelihood for the artisonal fishermen Unfortunately man-made environmental changes due to indiscriminate dumping of industrial wastes, domestic sewage, agricultural run off and soil erosion have frequently impeded the production process at different trophic levels of riverine fisheries of the country leading to low fish production Keeping this aspect in view CIFRI as part of their environmental monitoring programme of various river systems in the country initiated work on the River Damodar The river Damodar an important tributory of River Ganga is at present treatened by environmental constraints posed by the anthropogenic stresses Intensive investigation conducted by scientists of CIFRI for a number of years yielded valuable data sounding alarm for the ecological destabilization of this river This publication documents these significant findings I am hopeful that the data presented and the recommendations suggested for the conservation of this valuable ecosystem will be of immense use to all concerned

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INTRODUCTION

The river Damodar is one of the prominent tributaries of river Ganga. For ages the river was the cause of hope and despair to the inhabitants of the lower valley of the region, as it used to inundate vast areas, bring death and destruction to large number of human lives and property and thus, was considered as 'Sorrow of Bengal'.

Subsequently, on being tamed, this 541 km long tributary has become the life line of the vital industrial belts that have come up along the river bank in Bihar and West Bengal. The river Damodar flows through the mineral rich areas that produce about 37.2% coal, 35% bauxite and 43% mica in the country. Moreover, the river is the main source of water to the industries that produce 310 million tonnes of coal, 80 million tonnes of steel and 2,000 MW of thermal and hydel power, which together contribute substantially to the country's economy.

Such an indispensible vital water course is, affected by changing land use pattern, and badly stressed both physically and ecologically by the continuous dumping of solid rejects and silt load together with the discharge of excessively huge volume of industrial effluents. The river is gradually tending to be an ecological desert. CIFRI as a part of its environmental monitoring programme of various rivers in the country, carried out work on the river Damodar during 1992-95. The information generated is highlighted in the report.

Main Features of the River

1.	Length of the main stream	871.0 km
2.	Origin	Palamau hills in the western region of the State of Bihar.
3.	Catchment area	26,200 sq. Km.
4.	Geographic location	84°30' - 88°10' E and 22°10' - 24°50' N.
5.	Main tributaries	Sufi, Nalkari, Bhairavi, Konar, Bokaro and Barakar.
6.	Population of the basin	5.65 million
7.	No. of towns and cities	49
8.	No. of live coal mines	732
9.	Major industrial establishments	131 nos.
10.	Rainfall	1000 mm to 1800 mm.

TOPOGRAPHY AND HYDROLOGY

The river Damodar originates at the hills in Palamau district in Bihar, at an elevation of about 7-10 m above mean sea level. The river flows swiftly along stable course in south-easterly direction forming the boundary between Ranchi and Hazaribagh districts. In Bokaro district near Bermo town the Damodar receives the combined water of the forked twin tributaries - the Konar and the Bokaro and continues to flow eastward through the Dhanbad district (Fig. 1). Here the river widens but maintains a more c less defined course upto its confluence with the river Barakar. For some distance the river forms the border of the States of West Bengal and Bihar between the districts of Purulia and Dhanbad in the respective States. While entering West Bengal the river receives its principal tributary, the Barakar. The combined flow runs in south-easterly direction forming the border between the districts Bankura and Burdwan. This is the widest stretch of the river (about 2,500 m wide). After flowing another 80 km through Burdwan district it makes a sharp bend south-wards and divides into many channels. The main channel dwindles into an insignificant stream and joins the Hooghly river near Shyampur, while much of the water drains into the Rupnarayan river.

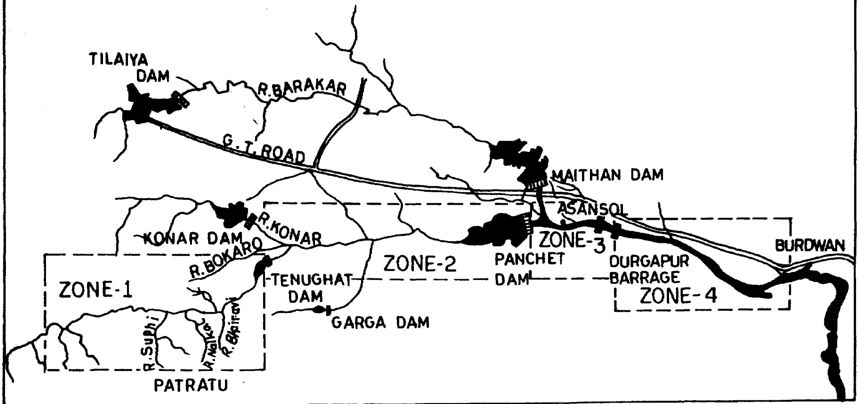
Water Abstraction

For centuries the huge quantity of monsoon water used to inundate the lower region of Damodar and adjoining areas. In order to minimise this perennial catastrophe and also to harness the potentiality of this huge influx of water, Damodar Valley Corporation was created. So far five reservoirs and one barrage have been constructed across the river to store 1,270 million m^3 of water. During nine dry months the river Damodar is allowed to maintain a perennial flow by regulating the reservoir sluices. Efforts are made to maintain the flow rate of 570 cusecs above Panchet dam, 430 cusecs for the next stretch upto Durgapur and below Durgapur 100 to 200 cusecs.The reservoirs, barrage, check dams and canals constructed across the river have resulted in the reduction of normal stream flow regime. Induced retardation in flow rate upsets the normal physiology of aquatic communities.

Silt and Sediment

River Damodar is a rain fed torrential river. Nearly 70% of the river course is in the valley. The river catchment is characterised by a prolonged dry season followed by turbulent monsoon with the annual run off, 11,385 million m^3 of water. The brief monsoon spell lasts just three months that contributes 90% of the total precipitation.

Fig. 1 : River Damodar showing zonations of study



Poor land management, denuded catchment, with favourable contour, high intensity of down pour and unrestrained industrial discharges are all together fast stressing the river, both physically and hydrobiologically.

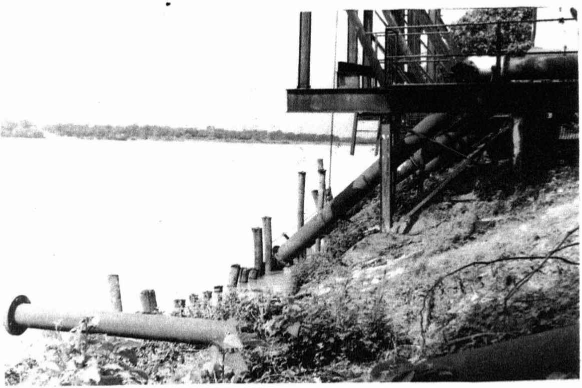
The rate of sediment production is far in excess of the rate worked out at the time of reservoir construction that has sharply reduced the calculated life span of the reservoirs. Hydrographic survey, conducted by the DVC, reveals that the sediment is getting deposited not only in the dead storage zone, as expected, but the live storage zone is also badly encroached. In the Panchet reservoir 47% dead storage and 23% live storage space have been lost during 29 years upto 1985. Likewise in the Maithon reservoir 43.2% dead storage space and 19.06% of live storage space have also been lost upto the year 1987 (Table 1). Similar depletions have also been observed in other reservoirs on the river.

Table 1: Rate of annual silt depositon (million m^{-3}) on the river bed - Estimated and Actual

Reservoir	Estimated Deposition	Actual deposition	% increase over the estimated rate.
Maithon	0.8187	7.1581	874
Panchet	2.3725	11.4110	481

The excessively high rate of sedimentation is fast reducing the carrying capacity of the river. The river bed upto the upper deltaic zone (Burdwan town) is already covered with a thick layer of sand with the formation of frequent sand dunes. The gorges and pools, so called sanctuaries for the bigger fishes, are getting silted up and the brooders are becoming easy prey to the fishermen. The breeding and spawning ground of various fishes are getting reduced. Thus, the high rate of silt deposition is not only reducing the river's fish population but the diversity also.

The disposition of fly ash has further deteriorated the condition. The fly ash with its greater surface area has made the river bed impermeable to a cosiderable extent. The toxicants released into the river get adsorbed at the soil water interface rendering the river bed sterile.



Water abstraction from the river for Industrial and other uses

Barricading of normal flow of water across the river

Damodar river in full flow during monsoon

A view of the river Damodar during lean period

INDUSTRIAL AGGLOMERATION

There are altogether 131 major industrial establishments (Fig. 2) excluding the coal mines along the river course which can be broadly classified as :

a) Coal mines
b) Coal washery, coal handling plant and coke oven plant
c) Thermal power station
d) Steel plant
e) Fertilizer, cement and chemical industry.

Coal Mines

It is mainly the coal bearing lower Gondwana region that predominates in the Damodar valley. They occupy 4,582 km^2 *i.e.* one tenth of the total area, and play a vital role in the economy of the region and also of the country. Coal reserve in this valley accounts for approximatly 36.5% of the country's total coal reserve of 186 billion tonnes. There are seven broadly identified coalfields in the Damodar trough *viz.* north Karanpura, south Karanpura, Ramgarh, west Bokaro, east Bokaro, Jharia and Raniganj. The Damodar flows through six of them while the Barakar hosts the east Bokaro field and part of west Bokaro before it joins the Damodar.

Mines continuously pump out ground/seepage water from the underground and the Damodar river receives mine water discharge in the range of 0.2 to 0.3 million m^3/d depending upon the operational variation (Table 2). Coal mines are scattered mostly along the left bank of the river from Rajarappa to Raniganj, a length of about 300 km with gradual increasing intensity. Accordingly, the impact of mine water in the river is found to be pronounced upto Durgapur.

Fig. 2. River Damodar with location of major industries

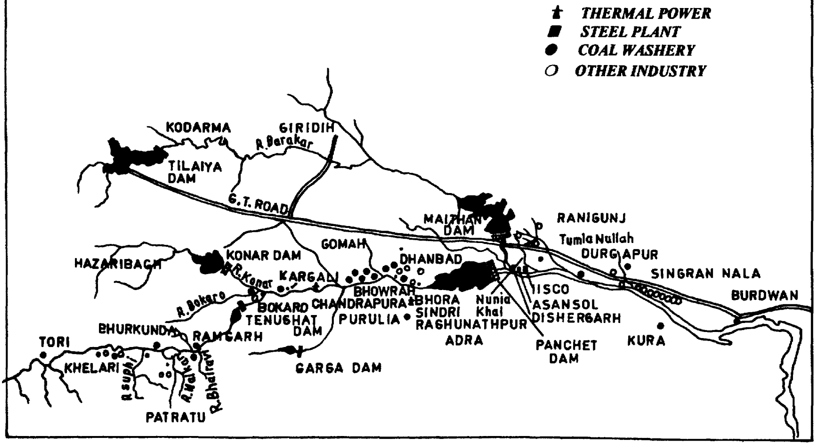


Table 2 : Quantum and Nature of effluents expelled into the Damodar by some major industries

Industry	No. of Plant	Quantum of effluent Mm^3/d	QUANTUM OF MAIN EFFLUENTS (tonnes per day)						
			TSS	TDS	Phenol	Ammonia	Oil & Grease	COD	Heavy metals
THERMAL PLANT	7	Fly ash 10,000 TPD	3000	900	...	...	1.358	39.5	Fe, Cu, Zn,Cd 0.04-0.28
LIVE COAL MINE	742	0.2-0.3	...	...	...	...	...	16-20	0.05-0.60
COALWASHERY	15	0.10*	4.0-12.0	4.0-7.2	0.8-1.2	...	0.001-0.002	4.8-6.4	Fe, Cu, Zn, Cd, Cr 0.01-0.20
STEEL PLANT	5	0.16	200-300	...	13.0-15.0	5.0-7.0	2.0-3.0	80-100	Fe, Cu, Cr, Zn 0.02-0.19
SINDRY FERTILIZER & A.C.C.	2	0.02	31.5	11.2	...	4.2	...	40-65	Fe, Zn 0.01-0.08
ASANSOL INDUSTRIAL COMPLEX (through Nunia Nullah)		0.007	1.4	1 4	0.2	1.8	0.5	2.8	Fe, Cu, Zn etc. 0.01-0.04

Contd. .... table 2.

Industry	No. of Plant	Quantum of effluent Mm^3/d	QUANTUM OF MAIN EFFLUENTS (tonnes per day)						
			TSS	TDS	Phenol	Ammonia	Oil & Grease	COD	Heavy metals
DURGAPUR INDUSTRIAL COMPLEX (through Singran Nullah)		0.008	10.5	1.4	0.2	2.6	0.6	3.2	Fe,Cu, Zn,etc. 0.08-0.40
(through Tumla Nullah)		0.12	49.3	18.3	1.6	2.3	1.2	41.6	-do-
DOMESTIC EFFLUENT		0.08	(47.459 TPD of BOD)						

*7000 MT/Yr solid rejects

The total toxic load that the coal mines water contributes to the river has been computed to be 16-20 tons/day COD and 0.05-0.60 tons per day of heavy metals. The average composition of heavy metals (mg/l) in mine water as registered were : Cu-0.23 to 0.72, Mn- 0.25 to1.12, Fe- 0.38 to 1.16, Ni - 0.10 to 0.23, Zn- 6.30 to 7.41, Co-0.08 to 0.12, Pb- 0.97 to 1.19, Cd-0.41 to 0.56 and Cr- 0.16 to 0.19.

Coal Washery

At present there are 15 coal washeries under operation in this coal belt which process 28.5 million tonnes of coal per annum. Another 3.00 million tonnes capacity at Kedla is awaiting operation.

Coal beneficiation process consumes water in the range of 0.20 to 0.25 m^3/tonne of raw coal input and the total demand of water is approximately 0.56 million m^3. It has been estimated that 10 washeries having washing capacity of 17.04 million tonnes of coal consume 70 million gallons of water and produce 2 million tonnes of disposable solids per year. Washery generates liquid effluents in the range of 12 to 18% of total consumptive water requirement. The washeries produce 3.7 million tonnes of solid rejects and tailings per annum of which 7,000 tonnes find outlets to river course through effluent streams and remaining undisposed quantities through rain water.

It is estimated that the coal washeries together expell into the Damodar 0.10 million m^3/d effluent that bears 4.0-12.0 tonnes of TSS; 4.0-7.2 tonnes of TDS; 0.8-1.2 tonnes of Phenol; 0.001 - 0.002 tonnes of oil and grease and 0.01-0.20 tonnes of heavy metals (Fe, Cu, Zn, Pb, Cr. etc.). The total COD load exerted by the effluxion is 4.8 - 6.4 tonnes/day.

The huge quantum of washery effluent brings severe ecological changes in the river water, specially during the lean period. It imparts brownish black colour to the river water and then transparency comes down below 10 mm due to high concentration of coal dust present in the effluxion. The ecology of the stretch between Rajarappa and Panchet reservoir of the Damodar river is under serious threat due to the influx of the washery effluents.

Coke Oven Plant

In coke oven plants coal is burnt in the absence of air to increase fuel efficiency. The steam that is employed in the process produces effluents although in low volume but with high level of tar oil, ammonia and phenol. The waste usually contains 1,100 ppm phenol, 60 ppm cyanide as HCN, 600 ppm HCNS as well as ammonia. It has been seen that at a dilution of 1:240 of this effluent fish stop eating and die. Most of the collieries and steel plants have ancilliary coke oven plant and the composite effluents are discharged excepting the Durgapur Coke Oven Plant.The Durgapur Coke Oven Plant has been found to discharge 45,450 KLD untreated effluents into the Tumla Nallah.

Thermal Power Station

The Damodar river system hosts at present nine thermal power and three hydel power stations having the generation capacity of about 3,000 MW of electric energy. Bokaro, Chandrapura, Durgapur and recently established Mejia thermal power stations are run by the DVC while the Patratu Thermal Power Station is run by Bihar Government and the Loyabad, Bhowrah and Jamadoba are captive thermal power plants.These huge power generating plants solely depend on the water from the Damodar river system.

It is on the record that the major thermal power stations produce an estimated amount of 12,108.0 t/d of fly ash of which about 3,269.16 t/d (approx. 27%) reach directly to the river and the rest through monsoon run off. The study conducted during 1994 reveals that the three thermal power stations *viz.*, Patratu, Bokaro and Chandrapura together generate 8,549 tonnes per day ash of which 2,356.40 t/d find outlets to river course through effluent streams and rest washed with rain water. The individual discharge rate and its character are as depicted in Table 3.

Table 3 : Characteristics of Thermal Power Station discharge in Damodar

Name of Power Plant	Discharge rate (m^3/d)	Total suspended solids		Oil and grease	
		Conc.(mg/l)	Load (T.P.D.)	Conc.(mg/l)	Load (t/d)
Patratu	5303.67	15145	1927.77	4.3	0.547
Bokaro	830.61	1619	32.27	6.8	0.135
Chandrapura	2387.96	6916	396.36	5.0	0.286

Disposal of Coal washery and other wastes
on the river front

A blanket of Coal dust over the river bed

Effluent from Cokeoven plant draining into the river

Steel Plant

Country's four major steel plants *viz.*, BASL, Bokaro, IISCO and DSP, producing 0.08 million tonnes of steel, draw mainly the water from the river Damodar. Water is among the most essential inputs for the iron and steel industry. Huge quantities of water are used in various processes, *e.g.* cooling and purification of coke oven gas that pollutes the water with tar oil, ammonia, phenol, cyanide, thiocyanate and thiosulphate which ultimately find their way through the effluents. Water from the blast furnace cooling-cleaning lines bear cyanide, fluoride, lead, zinc and huge suspensoids of dust particles. The steel making furnaces drain fluorides and zinc. Oil and grease come into the effluent from continuous casting and rolling mills casting operations.

The BASL at Patratu discharges its effluents into the Nalkari river that ultimately flows into the Damodar, while the Bokaro steel and IISCO drain their effluents directly into the river Damodar. The majority of effluxions from the DSP find their way into the Damodar through Tumla Nallah and only a fraction through Singran Nallah.

The total quantity of discharged effluents into the Damodar from the three steel plants *viz.*, Bokaro, IISCO and DSP amounts to 273.13 MLD. It is estimated that this quantum of effluents together contribute everyday 13.68 tonnes of phenol, 5.3 tonnes ammonia, 2.65 tonnes of oil and grease, 448.5 tonnes of TSS and 91.8 tonnes COD to the river course.

Fertilizer Plant

The Sindri fertilizer plant adds considerable toxic load to the river through its 21,000 kl/d discharge with 788.0 mg/l suspended solids and 290 mg/l ammonia nitrogen. The toxicants added are ammonia 4.2 TPD, oil and grease 0.1 TPD, TSS 31.5 TPD and some heavy metals.

Asansol Industrial Complex

Apart from collieries there are a number of major industries of multiple nature in Asansol zone. The effluxions of these industries are drained into Nunia Khal which finally flows into the Damodar at a point just above the Bengal Paper Mill. The river receives 7,000 KLD of effluents through this Khal, of which J. K. Nagar industries alone, discharges 3,000 KLD contributing 150 mg/l of TSS, 52 mg/l of COD, and 8.2 mg/l of oil and grease. The Reckitt & Colman expells 590 KLD with 380 mg/l COD and

124 mg/l TSS. An estimated 182 KLD is released from Carew & Co. bearing 16,500 mg/l COD, 5,060 mg/l TSS and 13,700 mg/l TDS. The quantum of effluents from the Indian oxygen is 600 KLD having the concentration of 200 mg/l TSS and 121 mg/l COD. Thus, the composite effluents contribute through Nunia Khal approximately 1.08 TPD TSS, TPD TDS, 0.2 phenol, 1.8 TPD ammonia, 2.16 TPD COD and 0.5 TPD oil & grease.

The Bengal Paper Mill discharges partially treated effluent directly into the river while the paper mill sludge are dumped just on the river bank which gradually finds its way into the river. The quantum of the effluent was 25 to 30 MLD contributing COD between 400 and 800 mg/l and TSS 400 and 1,500 mg/l.

Durgapur Industrial Complex

The industries in Durgapur, discharge maximum quantity of their effluents through the Tumla Nallah that joins the Damodar just below the barrage. A part of total discharge *i.e.*, only 7,700 KLD from the Durgapur Steel Plant is drained through Singran Nallah in the river. It has been estimated that Singran Nallah drains everyday 2.6 tonnes ammonia, 10.5 tonnes TDS, 1.4 tonnes TSS, 0.2 tonnes phenol, 3.2 tonnes nitrate, 0.7 tonnes oil and grease and 4.9 tonnes COD.

Tumla Nallah, the main outlet, drains 122.13 million litre of industrial effluent into the Damodar everyday that carries 2.34 t ammonia, 49.3 t TDS, 18.2 t TSS, 1.6 t phenol, 7.6 t nitrate & 1.2 t oil & grease and 46.1 t COD.

Total Industrial Discharge

The stretch between confluence of the Nalkari river and Damodar river upto Durgapur receives 1,11,700 MLD of industrial effluent loaded with 3,403 TSS, 938 TDS, 263 COD, 18.2 phenol, 17.9 ammonia, 6.76 tonnes oil & grease and 1.79 tonnes of heavy metals mainly Fe, Cu, Zn, Pb, Cr. and Cd. Table 4 depicts a detail break up of effluent loading and quantum of toxicants that the river receives.

Table 4 : Showing the towns along the bank of the Damodar their population and waste water generated

Town	Population 1991	Wastewater KLD	BOD load (kg/day)
1. Bermo	222,922	6243	4238
2. Bakri Saraiya	29,414	147	441
3. Kargali	26,897	879	533
4. Chandrapura	25,378	678	491
5. Bokaro	314,902	17917	7551
6. Kathhara	26,946	652	507
7. Dhanbad	236,578	9347	4968
8. Kerend	145,072	3849	2787
9. Sidi	138,557	7065	3185
10. Jharia	124,494	4539	2505
11. Joropokhar	129,848	4832	2676
12. Tisra	95,788	8564	1978
13. Bhowrah	67,787	26222	1396
14. Bhuli	73,051	2718	1505
15. Katras	58,134	2164	1197
16. Loyabad	54,223	1394	1010
17. Kumardubi	139,470	436	1311
18. Bhaga	47,239	1759	974
19. Jamadoba	73,309	1846	1021
20. Sigha	43,779	1631	903
21. Kenduadih	11,554	296	216
22. Gomoh	45,004	2707	962
23. Chirkunda	34,872	175	524
24. Maithon	28,013	1685	690
25. Pathardih	38,494	2695	962
26. Dumarkunda	20,339	102	302
27. Panchet	15,064	493	299
28. Angarpathar	24,899	642	465
29. Chaitudih	4,522	116	83
30. Chas	63,383	1484	1154
31. Netarhat	6,432	581	161
32. Hazaribagh	159,537	11983	3989
33. Saunda	122,107	611	1833
34. Jhumri Tilaiya	80,343	3752	1782
35. Ramgarh	94,933	1879	1936
36. Chatra	46,900	1417	908

Contd. ...... table 4.

Town	**Population 1991**	**Wastewater KLD**	**BOD load (kg/day)**
37. Patratu	186,839	5939	3605
38. Dishergar	86,832	2025	1468
39. Burnpur	174,933	4079	2958
40. Kulti-Barakar	108,518	2531	1834
41. Asansol	262,188	66144	4435
42. Asansol (Urban)	763,939	17815	12916
43. Raniganj (M)	61,997	8810	7680
44. Ranigan (M & O)	65,517	9310	8116
45. Raniganj (UA)	30,659	4357	3798
46. Ondal (NM)	16,288	2315	2018
47. Ondal (UA)	211,670	30080	26221
48. Durgapur	625,836	33220	30135
49. Burdwan	245,079	13009	11801

Municipal effluxion

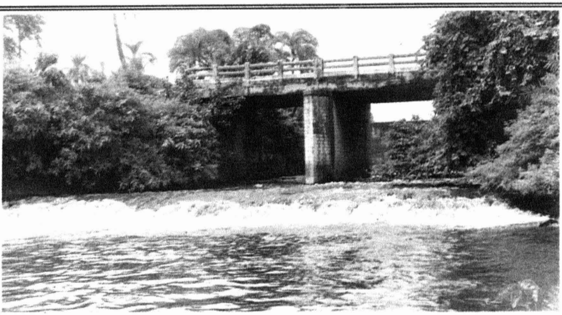
Mostly on the eastern bank of the river due to industrial infestation and mining operation, series of towns and intense urban settlements have come up. The towns like Hazaribagh, Ramgarh, Patratu etc., though away from the river course, discharges their municipal effluents into the river through tributaries and nallahs.

In Bihar there are 37 such sources having a total population of 3.05 million, whose discharges reach the Damodar. They together contribute 134.46 MLD of municipal waste water with the BOD load of 61.05 tons.

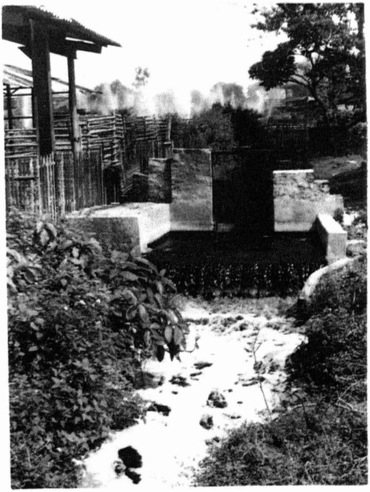
While in West Bengal there are 12 municipal, notified and urban areas that directly discharge their effluents into the Damodar, a total 2.6 million population of these human settlements generate 12.44 MLD of waste water with the BOD load 113.42 tons.

Thus, the riverine stretch from Bermo to Burdwan town receives 273.134 MLD of Municipal effluent with 174.43 tons BOD load per day.

Table 4 depicts townwise contribution of the municipal load against population.



Discharge from Tumnla nallah into the river Damodar



Discharge from Industrial unit finding
its way into the river

ECOLOGICAL SCENARIO

Water Quality

A detailed account of the water quality during 1992-95 is depicted in Table 5.

In stretch from Rajarappa to Tenughat reservoir (zone I) the water temperature during summer ranged from 30.0°C to 31.5°C as against 30.0°C during monsoon. The pH during summer remained between 7.8 and 8.2 while it was 6.5 and 7.5 in monsoon. The turbidity on an average was 360 mg/l in summer and 960 mg/l in monsoon. The alkalinity was moderate during summer (104-204 mg/l) but in monsoon lower values (34.0 - 64.0 mg/l) were registered. The estimated ammonia, nitrate and phosphate levels were moderate.

The next stretch upto Panchet reservoir (zone II)was mostly polluted by effluents from coal industries. This zone depicted oxygen stress with dissolved oxygen level during monsoon, below the critical level (1.7 - 3.0 mg/l) at a temperature range of 28.0°C to 29.5 °C. The turbidity of water during monsoon was 900 ppm and above and TSS values in range of 280 to 1,000 mg/l. The alkalinity values indicated narrow range between 55 and 66 mg/l while concentrations of ammonia and nitrate were on the higher side.

The stretch between downstreams of Panchet to Durgapur barrage(zone III) receives the effluents from the Burnpur-Asansol industrial complex. Just below Panchet the regulated flow of the Barakar river through Maithan dam increases the water volume. Here the water temperature during summer months was as high as 37.0°C and pH remained between 7.8 and 8.6. The turbidity ranged between 300 and 600 mg/l. Both ammonia and nitrate levels were very high in the stretch. During monsoon the ammonia content was estimated to range between 3.6 and 4.1 mg/l and nitrate 4.20 and 5.16 mg/l. The Durgapur barrage site had the ammonia and nitrate levels during premonsoon as 1.40 mg/l and 0.84 mg/l which increased in monsoon to 1.68 mg/l and 5.60 mg/l respectively. Durgapur industrial complex discharges its effluents below the barrage and the impact is felt upto Burdwan, though the stretch is having a considerable perennial flow.

At Pakhanna, a point about 5 km below the barrage, during the monsoon the turbidity varied widely between 200 and 700 mg/l, while in post monsoon the value was mostly above 350 mg/l. The pH was between 7.2 and 8.0. The ammonia concentration was in the range of 0.84 to 1.68 mg/l and nitrate level was also proportionately high.

Burdwan Sadarghat shows a recovery trend excepting the value of TSS which remains above 40 mg/l. It has been noted that during winter the transparency sharply increases and the turbidity values have been estimated to range between 300 and 400 mg/l over the entire stretch, excepting at the sites close to Kargali, Chandrapura and Dugdha.

Time Scale Changes

The water quality data for the upper stretch of river collected during the present study has been compared with the earlier data reported by Sinha (1988). Comparative variations in the physico-chemical environment of the river are depicted in Figure 3. The data reveals that in the upper stretch, zone I, there has been remarkable decline in the concentration of total alkalinity and total suspended solids during the period. But there has been a tremendous increase in the concentration of chemical oxygen demand. Such drastic changes are more pronounced in the zone II which receives about 127.1 MLD of industrial effluents in comparison to 30.2 MLD received by the zone I. It is also interesting to note that in zone II the concentration of dissolved oxygen and alkalinity declined by about 300% and 180%, respectively but at the same time values for TSS and COD showed a significiant increase reflecting the impact of stress which has increased through the years. But the time scale data available at present is not sufficient enough to draw any positive conclusion. One thing is clear that there is positive shift in the key parameters of water quality in the river system, especially at some of the centres which have been receiving higher discharge loads.

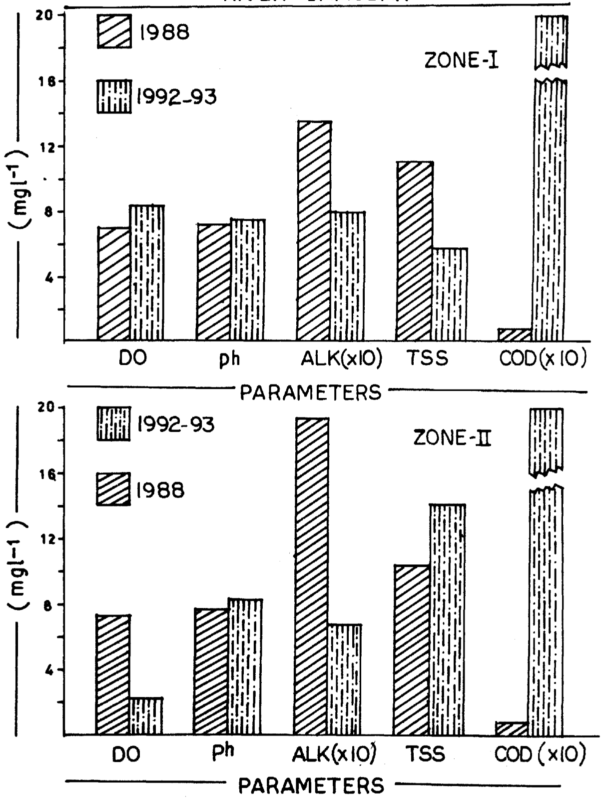
Table 5 : Water quality of the Damodar River during 1993-95

Zone	Year	Temp. 0°C	Turbidity (mg/l)	pH	DO (mg/l)	TSS (mg/l)	Phos-phate (mg/l)	Ammo-nia (mg/l)	Nitrate (mg/l)	COD (mg/l)	Phe-nol (mg/l)	Alkali-nity (mg/l)
Zone I (Rajarappa to Tenughat avg. of four (4) points.	1993	S 31.0	400	8.0	7.8	44	0.04	Trace	0.48	-	-	104.0
		M 30.0	900	7.2	7.2	60	0.06	0.56	0.81			64.0
	1994	S 30.0	350	8.2	8.2	38	0.02	0.28	0.29	27.2	-	168.0
		M 30.0	950	7.5	7.5	67	0.06	0.46	0.73	50.5		34.0
	1995	S 31.5	350	7.8	9.0	41	0.03	Trace	0.04	35.5	-	204.0
		M 30.0	1050	6.5	8.4	72	0.06	0.49	0.53	70.1		58.0
Zone II (Below Tenughat to Panchet) avg. of 14 points.	1993	S 30.5	700	7.1	7.0	500	0.27	0.84	0.28	98.1	-	60.0
		M 29.5	900	8.2	3.0	950	0.13	2.17	0.84	60.3	-	62.0
		W 23.0	200	7.4	5.9	320	0.30	0.28	0.56	76.0	-	59.0
	1994	S 31.0	300	7.0	6.8	380	0.51	1.70	0.35	58.7	-	55.0
		M 28.0	950	8.4	2.5	1000	0.65	3.70	0.90	100.2	-	66.0
		W 22.5	250	7.1	3.5	280	0.08	1.50	0.08	85.7	-	63.0
	1995	S 30.5	650	7.2	5.3	650	0.38	2.10	0.93	80.3	-	60.3
		M 29.0	900	7.9	1.7	870	0.43	3.21	0.87	80.7	-	61.0

Contd. ...... table 5.

Zone	Year	Temp. 0°C	Turbidity mg/l	pH	DO mg/l	TSS mg/l	Phosphate mg/l	Ammonia mg/l	Nitrate mg/l	COD mg/l	Phenol mg/l	Alkalinity mg/l
Zone III (Panchet to Durgapur Barrage) average of 10 points	1993	S 37.0	450	8.6	8.4	54	0.16	2.5	5.04	1160.0		86.0
		M 36.0	600	8.0	9.1	75	0.08	3.6	4.20	937.0	0.54	92.0
		W 23.5	300	7.8	8.0	40	0.60	0.8	6.06	636.0	1.38	120.0
	1994	S 36.5	350	8.4	8.0	48	0.07	3.1	4.08	1120.0	-	62.0
		M 36.0	580	7.8	9.3	61	0.28	3.7	4.76	1000.0	-0.48	68.0
		W 23.0	400	7.8	8.2	44	0.22	1.8	5.12	620.0	-0.48	85.0
	1995	S 37.0	500	8.0	7.8	40	0.21	3.7	6.03	927.0	-1.59	68.0
		M 35.5	550	8.0	8.1	68	0.18	4.1	5.16	830.0	-1.86	66.0
Zone IV (Durgapur toBurdwan) average 4 centres.	1993	S 31.5	680	7.4	7.6	50	0.08	1.40	0.32	1000.0	1.09	94.0
		M 30.5	450	8.0	10.5	96	Tr	0.86	0.32	1085.0	0.82	90.0
		W 23.0	110	8.1	8.1	16	0.02	0.81	0.32	699.0	0.98	123.0
	1994	S 32.0	700	7.8	7.0	47	0.04	1.21	0.27	900	1.27	100.0
		M 30.5	320	8.1	8.9	81	0.02	1.08	0.31	1000.0	0.78	82.0
		W 22.5	90	8.3	8.1	19	0.02	0.92	0.29	562.0	0.82	100.0
	1995	S 32.0	600	8.0	7.6	38	0.02	1.37	0.21	950.0	1.32	120.0
		30.0	250	8.3	8.1	96	0.06	1.00	0.32	1050.0	1.00	82.0

FIG. 3-TIME SCALE CHANGES IN WATER QUALITY OF RIVER DAMODAR



Biotic Communities

Plankton :

The Damodar is a fast flowing river, except during summer when the regulated discharge through the dams, transforms it at places into a thin sheet of water with sluggish flow. However, with the variation in seasons and changes in ecological condition distinct dominance of one group of plankton over the other is noted. Besides, the population structure of the river plankton, is conspicuously influenced by the planktonic inflow from the connecting hill streams or rivulets, which are mostly used as waste water drains by various industrial complexes and coal mines. Plankton, both in qualitative and quantitative terms often fail to behave as pollution indicator index, because of fast flowing ecosystem with innumerable inlets and for not having any locomotion of their own. However, plankton estimation over the time and space might depict an overall biological comparability of ecosystem.

Zone I :

In upper most hilly terrain the river is torrential and not conducive for growth and proliferation of the planktonic flora and fauna. As revealed from Table 6 the density of planktonic organisms ranged between 40 ul^{-1} and 156 ul^{-1} with average of 85 ul^{-1}. Though only 13 species of plankton were encountered, dominance of Bacillariophyceae was prevalent round the year (Table 7). Percentage of different groups was proportionate in the region. The connecting hill stream, Nalkari recorded low plankton population which influenced the plankton density of main stream at confluence point (15 - 56 ul^{-1}). In comparison, around the Gidi washery discharge point, draining of mainly organic waste, resulted in significant increased population :30 ul^{-1}).

Zone II :

The stretch between Tenughat and Panchet reservoirs showed improvement in species diversity with additional species recorded in comparison to Zone I. Despite increase in taxa and species number, the overall density of plankton declined by 236% (12-56 ul^{-1}; av. 36 ul^{-1}). Enhancment in Cyanophycean percentage and appearance of rotifer were the significant changes in species spectrum reflecting organic contamination in river at this zone. Seasonal abundance revealed monsoon to be favourable for planktonic proliferation (av. 42.28 ul^{-1}) against the dry period of winter (av. 21.20 ul^{-1}). Maximum planktonic density in this zone was recorded near Telmore bridge, Sindri Fertilizer effluent discharge point, and at the zero point of Panchet reservoir where the organic load in river sediment was also comparatively high.

Zone III :

Down stream of Panchet reservoir upto Durgapur barrage the river sustained higher density of plankton (16-604 ul^{-1} : av. 269.56 ul^{-1}) round the year. Seasonally monsoon was favourable for the plankton (av. 512.57 ul^{-1}) compared to winter (162.18 ul^{-1}), similar to trend noted in Zone II. During monsoon, the effluent from IISCO influenced the plankton density in the main river down the confluence point. With reduced discharge rate and prevalent semi stagnant condition at places in winter the river plankton depicted highly fluctuating distribution. At Chimakuri confluence, IISCO confluence and Nulia Nallah discharge points, the plankton populations was significantly low compared to the upstream population. The suppression of these organisms may be attributed to the toxic effect of the effluents brought in through these respective sources. In all 33 species inclusive of 25 phytoplankton and 8 zooplankton were identified from this zone in which *Anacystis* sp. dominated contributing 47.24% of the total plankton population. As a group Cyanophyceae ranging between 57.40 and 83.08% was maximum dominated by *Anacystis* sp., *Oscillatoria* sp. and *Phormidium* sp. Among the total plankton population, zooplankton formed only 3-3.6% in which 15.70-17.18% was contributed by rotifers while copepods and cladocerans formed 72.18-75.95% and 6.87- 12.12.12%, respectively. Dominance of cyanophyceae and rotifers among plankton populations revealed high organic load in the system in this stretch.

Zone IV :

The species diversity of the planktonic flora and fauna gradually declined in down stream of Durgapur barrage as the number of species recorded were 18 in this river stretch. The population density also declined (30-99 ul^{-1}; av. 50.11 ul^{-1}). These changes in plankton population was primarily due to dilution which some extent lowered the pollutional stress in the river.

Table - 6 : Zone-wise plankton distribution in Damodar River

Main Groups	ZONE I M	ZONE I W	ZONE II M	ZONE II W	ZONE III M	ZONE III W	ZONE IV M	ZONE IV W
	No of sp & (%)	No of sp & (%)	No of sp & (%)	No of sp & (%)	No of sp & (%)	No of sp & (%)	No of sp & (%)	No of sp & (%)
Chlorophyceae	3(23 66)	-	7(8 32)	6(33 59)	13(5 88)	12(9 58)	8(34 03)	6(13 85)
Cyanophyceae	2(10 04)	-	2(31 74)	2(16 41)	3(83 08)	3(57 40)	2(23 61)	2(26 63)
Bacillariophyceae	6(44 20)	-	10(41 91)	9(40 63)	9(7 40)	9(30 11)	6(34 03)	5(41 27)
Copepoda	1(19 20)	-	2(13 87)	1(4 69)	2(2 62)	2(2 21)	1(6 94)	1(18 25)
Cladocera	-	-	-	-	3(0 57)	1(0 50)	-	-
Rotifera	-	-	3(1 39)	2(1 56)	39(0 44)	1(0 20)	-	-
Protozoa	-	-	2(2 77)	3(3 13)	-	-	1(1 39)	-
Annelid	1(2 90)	-	-	-	-	-	-	-
POPULATION DENSITY								
Mean Ul^{1}	85 00		36 00		269 56		50 11	
Range (Ul^{1})	40 - 156		12 - 56		16 - 604		30 - 99	

M = Monsoon, W = Winter, sp = Taxa

Table 7 : Plankton diversity in Damodar River

Group / Species	ZONE I		ZONE II		ZONE III		ZONE IV	
	M	W	M	W	M	W	M	W
Chlorophyceae								
Eudorina sp.	-		-	+	+	+	+	+
Oedogonium sp.	+		+	+	+	+	+	+
Ulothrix sp.	-		-	+	+	+	+	+
Desmidium sp.	-		-	-	+	-	+	-
Spirogyra sp.	+		+	+	+	+	-	+
Closterium sp.	+		+	-	-	+	-	+
Pediastrum sp.	-		-	+	-	+	+	+
Akistrodesmus sp.	-		-	-	-	+	-	-
Coelestrum sp.	-		-	-	-	+	-	-
Crucigenia sp.	-		-	-	-	+	-	+
Hydrodictyon sp.	-		-	+	-	+	-	-
Scenedesmus sp.	-		-	-	-	+	-	-
Volvox sp.	-		-	-	-	-	+	-
Phacus sp.	-		-	-	+	+	-	+
Cyanophyceae								
Oscillatoria sp.	+		+	+	+	+	+	+
Anacystis sp.	+		+	+	+	+	+	+
Phormidium sp.	-		-	-	-	+	+	-
Bacillariophyceae								
Melosira sp.	-		+	-	+	+	+	+
Nitzschia sp.	+		+	+	+	+	+	+
Pinnularia sp.	+		+	-	+	+	+	+
Fragilaria sp.	+		+	+	+	+	+	+
Pleurosigma sp.	-		-	+	+	+	-	-
Melosira sp.	-		-	+	+	+	-	-
Navicula sp.	+		-	+	+	+	-	+
Synedra sp.	+		+	+	+	+	+	+
Cymbella sp.	-		-	+	-	+	-	-
Asterionella sp.	+		+	+	-	-	-	+
Surirella sp.	-		+	+	-	-	-	-

Contd. .... table 7.

Group / Species	ZONE I		ZONE II		ZONE III		ZONE IV	
	M	W	M	W	M	W	M	W
Rotifers								
Filina sp.	-		-	-	+	-	-	-
Keratella sp.	-		+	+	+	+	-	-
Brachionus sp.	-		+	-	+	-	-	-
Monostyla sp.	-		-	+	-	+	-	-
Lecan sp.	-		+	-	-	-	-	-
Protozoa								
Euglena sp.	-		+	+	-	-	-	-
Arcella sp.	-		+	+	-	-	-	-
Annelids	+		-	-	-	-	-	-

Benthos

Benthic organisms which are integral part of the biocommunities and a vital component of the food chain are highly sensitive to the ecological changes. The large stretch of Damodar river bed which is blanketted with oil mixed fly ash does not support the proper growth and multiplication of wide variety of benthic flora and fauna. The predominance of oligochaetes and chironomids have been observed over the river bed upto Durgapur.

The benthic population at Rajarappa centre (Zone I) have been estimated to be low (10-40/ m^2; average 25.0/m^2) and represented mainly by oligochaete worms and chironomids occasionally (Table 8). The SDI values were very low, always below 1.0. Oligochaete and chironomid worms both being indicators of eutrophication, this centre appears to be organically polluted.. But the complete absence of molluscs and other benthic fauna does indicate unsuitability of the river bed for colonisation of diverse benthic fauna, which is attributed to the thick deposition of coal dust particles at the river bed.

Table 8 : Distribution of benthic fauna in Damodar River

ZONE	Density(No/ m^2)	Important forms
I	25 (10-40)	Oligochaete worms
II	311 (NIL-3540)	Oligochaete worms *Thiara* sp. *Pleurocera* sp. Chironomid worms Fly nymphs
III	160 (30-600)	Oligochaete worms *Thiara* sp. *Pleurocera* sp. Chironomid worms Fly nymphs Mosquito larvae
IV	90 - 100	*Gastropod shells

*Empty shells of gastropods were encountered in large number

In Bokaro zone (Zone II) the average density of benthic fauna was estimated to be high (nil to 3540 u/m^2; average 311 u/m^2) compared to the upper stretch. But the organisms were unevenly distributed; maximum near Telmora bridge (average 3540 u/m^2) followed by Chandrapura point (770 u/m^2) and in other points mostly below 270 u/m^2. Oligochaete were encountered over the entire zone while gastropods (*Thiara* sp., *Pleurocera* sp., *Lymnaea columella*) could be recorded from a few sampling points in this stretch. Occasional appearance of gastropods might be due to the flattening of the river bed and formation of small shallow depressions, that have provided shelter and food for the gastropod colonies.

In Durgapur zone (Zone III) the population density fluctuated between 30 u/m^2 and 600 u/m^2 (average 160 u/m^2). Like the upper stretches this zone registered the dominance of oligochaetes and gastropods but in lower densities. The only centre near outfall of Nunia Khal, registered higher density of benthos dominated by gastropods.

All the sampling points under Burdwan zone (Zone IV) showed the presence of empty gastropod shells and thus indicated riverine pollution due to toxicants causing mass mortality of the animals. Chironomids in higher concentration (90 to 100 u/m^2) were encountered in this stretch, an indication of high organic load.

Fish and Fishery

River Damodar has never been a potential fishery resource, neither there has been any well defined commercial fishery specially in the upper and middle valley regions due to the typical physiography. This stretch experiences a devastating torrential flow during monsoon and in summer a narrow few centimeter deep meandering water strip and obviously could not harbour any commercial fishery.

In the upper most river stretch from Tori to Bhurkunda the species encountered were mostly minows found in torrential waters represented by *Barilius* sp., *Puntius* sp., *Noemachilus* sp., *Ambassis* sp. and *Chela* sp. Between Rajarappa and Tenughat mainly carps, found in mountain foothills namely *Labeo boggut, L. dyocheilus, L. calbasu* and *Barilius* sp., were encountered. The catfishes like *Mystus seenghala, M. aor, M. cavasius, Ompok bimaculatus*, and *Clupisoma garua* were also encountered. Hill stream species like *Hara* sp. *Glyptothorax sp., Amblyceps sp.* were also collected by scoop net and cast net from the stretch. At Rajarappa and Bhandaridaha the gorges probably act as sanctuaries for the large size fishes which are caught at these centres.

In the stretch between Tenughat and Panchet reservoirs the fish species encountered were carps mainly *Barilius sp., Puntius sp., Labeo sp., Cirrhinus mrigala and C. reba*, catfishes like *Mystus seenghala, Wallago attu, M. cavasius, and Clupisoma garua* and the hill-stream forms represented by *Chela* sp., *Glyptothorax sp., Barilius* sp. etc. other species *viz., Channa puctatus, Puntius sarana, Heteropneustes fossilis, Amblypharyngodon mola and Esomas danricus.*

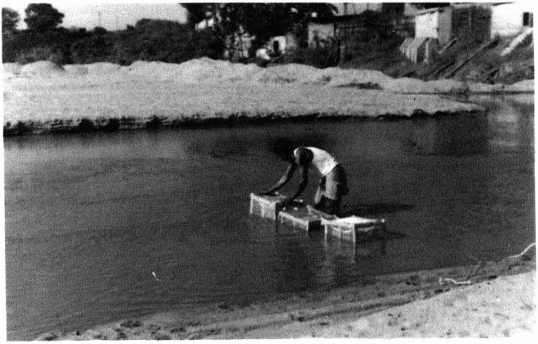
Below Panchet, the Barakar river joins the Damodar near Chirkunda and maintains a perennial flow with considerable volume of water upto Durgapur barrage. Moreover, the river gradient in this stretch being 1: 2,000 harbours a wide variety of fishes and support commercial fishery to some extent. The fishes encountered in this stretch were *Catla catla, Labeo rohita, L. calbasu, L. bata, C. mrigala, C. reba, Puntius conchonius, M. aor* etc. But this stretch being polluted with dissolved and suspended chemicals the fishes found here were mostly impaired in their growth.

In comparison in down stream of river upto Burdwan Sadarghat, the fish diversity remains almost same but the fishes were comparatively healthy.

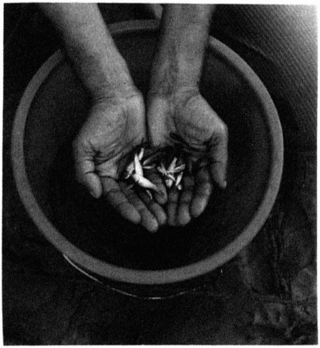
Fishery resources of the river were also investigated by CIFRI during early fifties prior to harnessing the river for various development projects. As reported, total of 89 species of fish belonging to 20 families were encountered during the survey and

Fish haul from Durgapur barrage on the river Damodar

Fish haul at Bardhman stretch of the river Damodar



Laying of *in situ* bioassay experiments in the river Damodar



Test fishes used for conduct of bioassay experiments

25 species were considered to be of commercial importance. During the present study only 56 species belonging to 21 families could be recorded out of which 16 species representing 6 families are having economic value. Table 9 elucidates a picture of fishes recorded in three stretches during the present study.

Table 9 : Fish spectrum in different reaches of Damodar River (1992-94)

Commercially important species	**Upper (Tori above Panchyet)**	**Middle (Disergarh-Durgapur)**	**Lower (Durgapur-Burdwan)**
1. Barilius bola	+	+	+
2. Puntius sarana	-	+	+
3. Catla catla	-	-	+
4. Cirrhine mrigala	-	+	+
5. C. Reba	-	+	+
6. Labeo rohita	-	-	+
7. L. calbasu	+	+	+
8. L. Boga	+	+	-
9. L. Boggut	+	+	-
10. L. Dyocheilus	-	+	-
11. Ompak bimaculatus	+	+	-
12. Wallago attu	-	+	+
13. Mystus seenghala	+	+	-
14. M. Aor	+	-	+
15. R. Rita	-	+	+
16. B. Bagarius	-	-	+
17. Clupisoma garua	+	+	+
18. Labeo bata	-	+	+
19. Bhincmugil coraula	+	+	+
Non-commerically important species			-
			+
20. Notopterus notoptarus	-	+	+
21. Chela gora	+	+	-
22. Chela sp.	+	+	-
23. Barilius barila	+	+	-
24. B. Bendelisis	+	+	-
25. Barilius sp.	+	+	-
26. Esomus danricus	-	+	-
27. Amblypharyngodon mola	-	+	+
28. Aspidoparia morar	+	+	-
29. Puntius sophore	+	+	-
30. P. Conchonius	+	-	-
31. Garre spp.	+	-	-
32. Botia spp.	+	+	

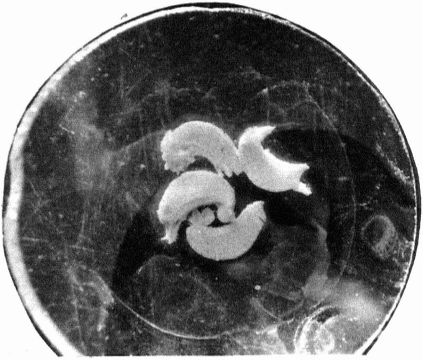
Contd...... table 9.

Non-commerically important species			
33. Nemachilus spp.	+	+	-
34. Mystus cavasius	+	+	-
35. Glyptoth sp.	+	+	-
36. Hara sp.	+	+	-
37. Clarias batrachus	+	+	-
38. Heteropneutis fossilis	+	+	-
39. Xenortodon cancila	-	-	+
40. Channa punctatus	-	+	+
41. C. Striatus	+	-	+
42. Glossogobius giuris	-	+	+
43. Ambassta bacilis	-	-	+
44. A. Nama	+	+	+
45. A. Ranga	+	+	-
46. Masteembelus armatus	+	+	+
47. M. Pancalus	+	+	+
48. Amblyceps sp.	+	+	-
49. Dorishthys cuncunus	+	+	-
50. Ailia coilia	+	-	-
51. Amphipnous cuchia	+	-	-
52. Coliaa faciatus	+	+	+
53. Apocnyptis sp.	-	+	-
54. Coliaa faciatus	-	-	+
55. Apocnyptis sp.	-	+	+

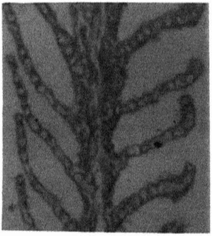
In situ Bioassay

In situ bio-assay experiments conducted in all the four zones provide in depth location-specific evaluation of toxicity of the river water in relation to fishes. This study gave a better understanding of the impact of toxicants present in water directly on the aquatic life compared to the assessed degree of eco-degradation.

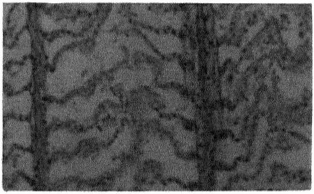
Three species of Indian major carp *viz., Catla catla, Labeo rohita* and *Cirrhinus mrigala* were taken as test species and are among the rare fish varieties available in the Damodar river at the present. These test species were exposed to the river water at Rajarappa, Bokaro, Durgapur and Burdwan for 96 hours and LC_{50} value has been worked out. The following table (Table 10) is self explanatory.



Choking of fish gills with coal dust



Normal gill structure of test fish
before *In situ* bioassay exposure



Gills showing tissue aberrations after
in situ bioassay exposure of test fishes

Table 10 : *In situ* fish toxicity-bioassay in river Damodar

ZONE	LT_{50} (hrs.)	
	Observed	Extrapolated
Rajarappa	65 - 72	69
Bokaro	38 - 50	48
Durgapur	42 - 48	44
Burdwan	66 - 78	70

It is evident from the above table that the exposure sites at Bokaro and Durgapur were more toxic to the test animals. This corroborates with the hydrobiological conditions as evaluated over the entire stretch from Bokaro to Durgapur. The study further reveals that the stretch below Durgapur shows a rapid recovery as no industrial effluent except the discharges from Tumla Nallah reaches directly in this stretch.

Stress impact on exposed and natural population

The external examination of test fishes reveals that at Rajarappa and Bokaro exposure sites the test fishes succumbed to respiratory stress due to the deposition of coal dust particles and fine silt on the gills. While at Durgapur and at Burdwan the external examination did not reveal any coal dust deposition on the fish gills. Here the mortality might be due to other toxicants present in water.

The microscopic studies of the fish gills showed various deformities at celluar levels. The damages mainly were noticed to occur in the primary and secondary lamellar structures. Erosion of epithelium was at various degrees and recorded at the highest level at Bokaro point. Under extreme conditions the lamellar tips swelled and the red blood corpuscles concentrated in the swelled portions of the lamellae.

The natural population of the riverine fish when clinically examined revealed that the species of *Barilius*, very common in the upper stretches of the river, showed the signs of gill damages like lamellar fusion, clubbing and in some cases acute hyperplasia which are the impacts of long term suffering of the inhabitant fishes under stressful environmental conditions.

CONCLUSIONS

a) The present physical and hydrobiological condition of the river Damodar has deteriorated. The post independence changes in land-use pattern along the banks of the river, after being harnessed by the DVC, have resulted in a severe ecological stress. The river has lost its natural flow pattern and excepting for monsoon it is reduced into a drainage channel and receives discharges from numerous industries that flank along its banks. This impact is felt maximum in the river stretch between Tenughat and Panchet reservoirs.

b) Due to topographic advantage the upper most stretch upto Tenughat is less polluted. Here, both the impact of human habitation and industrial effluxion are low. However, the fast denudation of the catchment forest cover has increased the silt transportation rate many folds, and numerous check dams have accentuated the rate of silt deposition. This has resulted in rapid silting up of the gorges, the main sanctuaries of the large fishes.

c) The middle stretch that extends upto Panchet reservoir is worst affected. This stretch receives maximum quantity of industrial and municipal discharge and receives minimum water flow, through the sluices of Tenughat and Konar reservoirs which does not help toxicant dilution. During 1995, the average discharge rate from December to May, the non-monsoon period, was registered to range between 1.1 and 9.2 cusecs, the maximum being 50.23 cusecs during December. In monsoon the average discharge rate increased to 412.6 cusecs in September. The annual flow rate seems to be insufficient to dilute the huge industrial load from three thermal power plants, ten coal washeries, steel and fertilizer plants (one each), and numerous other small industries. Thus, the endemic fishes in this stretch are under extreme stress.

d) This study has shown that big industries located in this area are primarily responsible for degrading the ecosystem. Inspite of installing some effluent treament plants, no significant improvement has taken place because more often they are found to be inoperative or not functioning. Moreover, the release of water from the reservoirs being very irregular, the flow rate varies frequently which upsets the normal life cycle of the biotic communities.

e) The part of middle stretch, upto Durgapur Barrage receives mainly the effluents from IISCO, Bengal Paper Mill and a good number of other major industries that discharge their effluents into the Nunia Khal. This stretch bears the combined discharge of the rivers Damodar and Barakar released from the reservoirs Panchet and Maithon respectively. Accordingly, the quantity of effluent discharge is comparatively high. The discharge rate during lean months varied between 24.6 and 48.7 cusecs which further reduced to 9.3 cusecs during May 1995. This stretch being on low gradient maintains considerably more volume of water and could harbour bigger sizes of commercially important fishes. But the water quality at Dishergarh indicates that the Barakar water could not mitigate the toxic load of the water released from Panchet as evidenced from disproportionate growth of the fishes caught in this stretch.

The most pronounced human activity that threatens the existence of the river is the indiscriminate dumping of the solid rejects mostly from open cast mining and other industries. The dumps along the banks are narrowing the river course and as well raising river bed together with drifted sand and fly ash.

f) The stretch below Durgapur Barrage is having a perennial flow between 100 and 300 cusecs and runs almost over the plain. The combined industrial effluent discharge through Tumla Nallah pollutes this stretch. The pollution effect is felt upto Burdwan town a distance of about 40 km. This destroys the fishery to a considerable extent.

g) In the present study the inlets into the river have been identified which are major contributors of pollutants , they are the Nalkari above Rajarappa, the Giddi and Rajarappa washery inlets, the drains carrying ash slurry from Bokaro (A & B) and Chandrapura thermal power plants, the inlets from Kargali and Dugdha washeries, the FCI effluent discharge point above Gorgari ghat and the IISCO drainage, the Nunia Khal and the Tumla Nallah.

h) The toxicants those have been identified to be more pronounced in polluting the river water are the heavy metals, oil and grease, phenol, TSS and nitrogenous compounds.

i) The fish species which abound in such environment, reveal through clinical examination to have definite impact of these pollutants. The normal growth and multiplication of the prized Indian major carp and prawn under the existing ecological status of the river and the reservoir are badly affected. As compared to the fish diversity during 1957, already 33 species of fish have been found to be endangered out of which 9 are commercially important.

RECOMMENDATIONS

Based on the informations generated during the present sutdy some remedial measures are proposed which may help in conservation efforts.

1. The aforestation process need to be accelerated. The banks of the stretch between Bokaro and Panchet is almost devoid of any vegetation. The human habitation, coal mines, dumps of solid rejects and sand dunes restrict the natural vegetative covering. Private sectors should be entrusted to develop the greenery over these areas or a mandate should be given to the industries/ notified area authorities/ municipal bodies to plant trees in the areas under their control.

2. All the dumps of solid rejects along the banks may be removed with immediate effect and further dumping to be banned by proper legislation.

3. The present practice of the river water management by three different authorities should be replaced by a APEX Body in order to bring an uniformity in water management and to protect the interest of the industry, fishery and agriculture.

4. The barriers and barricades errected on the river during the lean periods to facilitate water lifting and transportation across the river should be strictly prohibited.

5. Strict compliance on establishing effluent treatment plant should be ensured in case of polluting industries.

6. Water quality monitoring programme at vital places on the riverine stretch on a monthly basis to be carried out and data base to be generated for guidance of user industries. It may be looked after by the proposed APEX body.

7. The Central Inland Capture Fisheries Research Institute, engaged in the environmental studies of open waters, should be involved in major development programmes involving modifications of inland waters which are likely to affect fish biodiversity in particular.