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Original Article

Industrial Pollution Assessment of Tamla Rivulet in Industrial Town of Durgapur, West Bengal, India: Hazard Analysis Through GIS

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Abstract

The vehemence of industrial pollution has been studied along a stretch of effluent discharged canal, the Tamla Rivulet in the industry-intensive town of Durgapur, West Bengal, India. The present study monitors the surface water quality and relates it to the land use / land cover maps using Remote Sensing and Geographical Information System (GIS) techniques. Middle stretch (industry-rich) and lower stretch of Tamla (confluence area) manifested considerable pollution effects in surface water, ground water quality and agriculture, respectively compared to the upper stretch. The maximally affected lower Tamla region recorded high concentrations of phenolic compounds in ground water and concentrations of fluoride, lead, cadmium and chromium in the drinking water. The calculated industrial hazard index revealed that outfalls of industries in the middle and lower Tamla region exhibited very poor and poor water quality, respectively affecting the overall eco-biological health of the entire zone.

Keywords: Industrial Pollution; Surface Water; Ground Water; Industrial Hazard Index.

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Introduction

Water is one of the most important constituents of life support system and a chemical medium with a unique property of dissolving and carrying in suspension a variety of chemicals and other materials (Kulshreshtha, 1998). Any material (or heat) harmful to humans, animals or desirable aquatic life when carried in excess amount causes water pollution (Katyal, 1989; Vorosmarty et al., 2000; Bhatia, 2003). It is a vehement global problem caused by various kinds of natural and man made activities such as agricultural, industrial, domestic and others affecting fresh water (lentic and lotic) bodies (Ramkrishna and Babu, 1999; World Bank, 1999; UNESCO, 2003; Puyate et al., 2007; Amaal et al., 2009), marine aquatic system (Edwards et al., 2001; Ylitalo, 2005; Verlecar, 2006; Saraswat et al., 2007) and ground water systems (Barber et al., 1998; Otto, 1999; Kinniburgh and Smedly, 2001; Chisala et al., 2004). Humans, especially young children and foetuses are very sensitive to heavy metal pollution of water (Jayprakash, 2005; Susheela et al., 2005; Pandey et al., 2010). Other severe cases of human health hazards (WHO, 2001; Chandrasekar, 2002; Clark et al., 2003; Rahman et al., 2005), aquatic food chain toxicity (Simon et al., 2005; Ekambaram et al., 2004; El. Shimy et al., 2007; Benson et al., 2007; Silva and Shimizu, 2004; Sciencedaily, 2008) etc have been reported from world wide.

Durgapur city, the industrial metropolis of the state of West Bengal, India, is also one of the largest industrial cities of India. It covers an area of 154 sq km of which 13% is under industries and the rest is covered by settlements and cultural establishments. It serves as the home for a number of industrial units such as Durgapur Steel Plant, one of the integrated steel plants of Steel Authority of India Limited. Alloy Steels Plant of SAIL is also located here along with a number of power plants, chemical, engineering and metallurgical industries. Development of such an industry rich zone is due to its favourable position in respect to raw materials (good quality iron ore, coal and lime deposits), fresh water supply and easy transport for labour and market. As a result of this industrial activity, the basin draws about 329 MCM of water per year. At least 92.81 MCM of the water is

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returned to the Damodar river (south of Durgapur) as an untreated effluent (CSME, 1998). The annual pollution load of the entire Damodar river (CSME, 1998) has indicated a high discharge (tones / year) of iron (16,800), copper (3,990), cadmium (470), chromium (1960) and phenolic compounds (1211).

The industrial effluents are discharged through the Tamla and Singaran Rivulets and hence the study has been done with specific reference to these discharge routes.

In this zone human populations and ecological receptors are in continuous contact with these industrial discharges because they are present in air, water, soil and food. These links manifest themselves through their effect on human health and ecology. Therefore, the link demands exact identification of the causes for formulation of sound environmental planning thereby necessitating studies and analysis of environmental hazards of the area. The environmental planning calls for scientific, eco-friendly and planned waste discharge methods, sites and treatment facilities in this area for most of the industries. To provide a comprehensive but easy to use tool in the assessment and evaluation of water quality in the industrially polluted area, the concept of water quality index (WQI) can be used (Lermontov, 2009) This index coupled with available pollution data after integration spatially in thematic maps prepared by interpretation of satellite imagery using a computer based analytical system of GIS (Asadi et al., 2007) will help in the environment planning and decision support system of the study area. The present study aims for development of the eco-health of the region through the seasonal and spatial analysis of effiuent load in outfalls of 5 major industries along the middle and lower stretch of Tamla and studying their effects on agricultural produce. Industrial Hazard Index (IHI) of the region has been generated for future risk analysis.

Materials and Methods

Study Area

Location

The study area is located between 23°20' to 23°30' N latitude and 87°15' to 87°30' E longitude along the left bank of river Damodar in the Durgapur city, Barddhaman district, West Bengal, India (Figure 1).

Climate

Extremely hot and humid summer persists from mid April to mid June. Rainy season starts from mid June to mid August with an annual precipitation of about 1424mm (Roy and Chakrabarty 2004). Winter is moderately cold and starts from November and lasts till February. Mean annual maximum and minimum temperatures are 42° C and 21.5° C respectively.

Soil and Drainage

Colour-Greyish brown, near neutral to slightly alkaline sandy clay loam in nature and medium to moderate sub-angular rocky in structure. The area is an interfluvial tract of the drainage system

i. two main rivers viz. Ajoy and Damodar flowing from west to east,

ii. two minor streams namely Tamla, rising just south of the village of Ukhra in Andal,

iii. rivulet Jor originating from north western direction of Banskopa village in Rajbandh.

Both the streams are joining the Damodar at Madhya Mana and Napara village respectively (Figure 2).

Experimental Sites

For the selection of suitable sites, the entire stretch of Tamla rivulet was categorized into three zones-upper Tamla (A), middle Tamla (B) and lower Tamla (C) based on the number of waste water outfalls into the rivulet from the different industries (Table 1). The outfalls of Alloy and Steel Plant (ASP) and Durgapur Steel Plant (DSP) are located in the middle segment whereas Durgapur Chemicals Limited (DCL) , East India Pharmaceuticals Works Limited (EIPWL) and Durgapur Projects Limited (DPL) near north-west of Ashishnagar area are located in lower stretch Five experimental sites, two located in the middle stretch and three in the lower stretch of Tamla rivulet, were selected altogether, each at the outfall point of DSP, ASP, DCL, EIPWL, DPL to study the surface water pollution. Map showing sampling points overlaid on satellite imagery is shown in Figure 3.

Further, three other places adjoining to Tamla rivulet corresponding to upper, middle and lower stretch (Table 2) were selected to study the pollution effect in groundwater, soil, and vegetations.

Sample Analysis

Collection of Samples

Samples of surface water, groundwater, soil and vegetations were collected monthly over 4 years duration

Water

Samples of surface were from each site in 250 ml closed plastic container. Groundwater samples were taken from deep and shallow tubewells.

Soil

At each of the sites, one 100 x 100 m permanent plot was demarcated. Ten samples were collected randomly from the upper 10 cm layer (in 5x5x10 cm blocks) of each of the plots and the samples were divided into two parts, one part of which was sieved through a 2mm mesh screen. The screened samples were then mixed together and four subsamples from each site were drawn for further chemical analysis.

Vegetation

Vegetables grown in the experimental regions were also sampled in three replicates of 5 grams each for every vegetable of each site during winter seasons. The large pieces of plant materials were hand picked. Fine roots were carefully removed.

Testing of Samples

Surface and Groundwater

Samples were tested for magnesium, calcium, total hardness, alkalinity, chloride, total conductivity, pH, total dissolved solids, total suspended solids according to APHA (2005).

Soils

Mechanical analysis was conducted through pipette method ((Black et al. 1965) on the unsieved soil samples. pH was measured with pH analyzer. Materials prior to weighing were dried at 40°C. All the materials were grinded to pass through a 0.25 mm mesh. Iron, copper, zinc, chromium and magnesium were estimated through an atomic absorption spectrophotometer. Manganese and calcium were analysed by EDTA method (APHA 2005).

Total nitrogen was analysed according to macrokjeldahl analysis acid extraction method (Moore and Chapman 1986) and available N measurement as per Jackson (1958) and Wetzel and Likens (2000). Available phosphorus was measured through spectrophotometric method (TSBF, 1989). Organic matter was evaluated by multiplying 1.724 (Bemmelen factor) with the organic carbon content, the latter was measured by Walkley Black rapid titration method (Jackson, 1958). Atomic absorption spectrophotometer was used for heavy metal analysis of soil samples.

Vegetables

Three replicates of 5 mg of each vegetable from each site have been considered for analysis. Materials prior to weighing were dried at 40° C. All the materials were grinded to pass through a 0.15 mm mesh. Retained a representative sample of approximately 25 mg, eg coning and quartering, for analysis in 5 gm of each replicate. Iron, copper, zinc, chromium, cadmium and magnesium were estimated through Atomic Absorption Spectrophotometer (AAS). Magnesium and calcium were analysed EDTA method (Clesceri et al. 1998).

Spatial and Attribute Database Generation

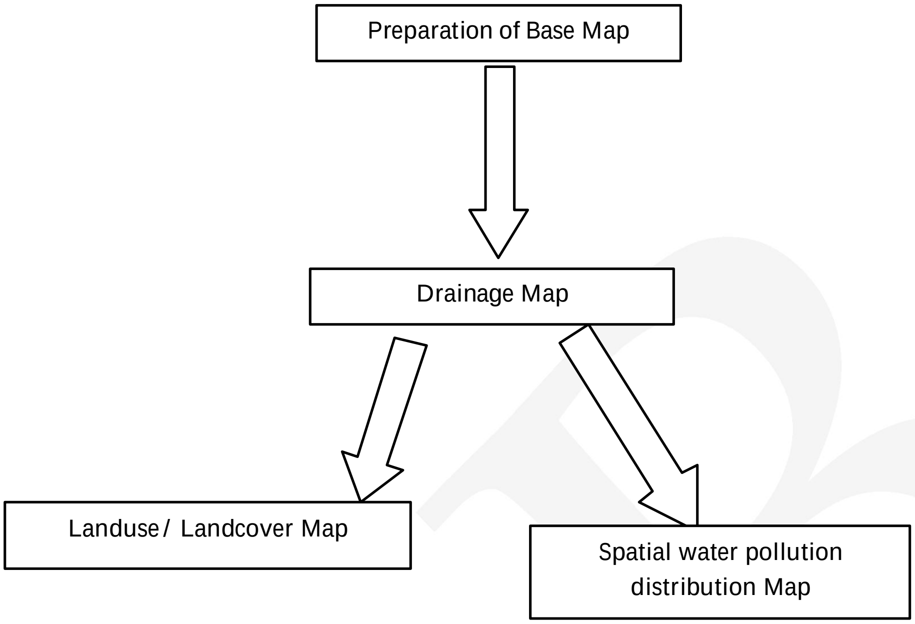
Preparation of Base Map

Thematic maps like base map and drainage maps (Figure.2) are prepared from the SOI toposheets (73 M/2,73 M/6 and 73 m/7) on 1:50,000 scale. These Thematic raster maps are converted to vector format by scanning and digitized in Arc GIS 9.3 (Version) software to obtain a baseline data in digital mode.

A landuse / landcover map (at 1:162997 scale) was prepared using on screen digitization technique from IRS-ID,LISS-IV satellite imagery and SOI toposheet along with ground truth verification (Figure 4)

Integration of Spatial and Attribute Database

The spatial and the attribute database generated are integrated for the generation of spatial distribution maps of selected water quality parameters like pH, alkalinity, chlorides, sulphates, nitrates, TDS, total hardness, fluorides and Industrial Hazard Index (IHI) and overlaid on satellite imagery. The water quality data (attribute) is linked to the sampling location (spatial) in ARC / INFO and maps showing spatial distribution are prepared to easily identify the variation in concentrations of the above parameters in the ground water at various locations of the study area using curve fitting technique of ARC / VIEW GIS software.



Calculation of Industrial Hazard Index

Industrial Hazard Index of surface water (IHI_{sw}) =

$$\frac{\text{Concentration of effluent at the outfall point}}{\text{Permissible limit of the effluent}} \times 100$$

All data were tested statistically for significance using LSD (Least Significance Difference) for relevant parameter.

Results and Discussion

Seasonal Variation of Surface Water Quality

The pre-monsoon period have a higher pollution load (Table 3) due to low discharge of water in the rivers and a low pollution load in the post-monsoon season owing to the effect of dilution brought about by higher discharge of water due to rains. But in the present case it is not always so. Further, because of the topography, there was a considerable amount of mixing of water of both the regions during the monsoon season consequently the difference in quality of water in up stream and down stream part decreased.

The industry-wise seasonal variation of different parameters is as follows :

pH

The values of pH at the effluent discharged points of Tamla rivulet for all the industries showed a fluctuating trend throughout the year. The value of pH ranged from 8.9 (EIPWL-winter) to 5.9 (DPL-February). The high pH value of water in the down stream region and its large fluctuation was related to the effluent discharged from DSP Steel Plant which varied from time to time depending upon the production schedule and quantity of municipal effluent entering to the river (Table 3).

TSS

The concentration of TSS remained low all throughout the year for ASP and DCL. The values remained comparatively higher during April to October than the remaining months although a fluctuating trend has been noticed all throughout. An unusual high value of 222.4 mg/l was observed at DPL outfall point in July (Table 3).

COD

The value of COD in the outfall point of EIPWL was markedly high (96 to 228 mg/l). This was followed by DPL (27 to 81.4 mg/l). The COD concentration ranged from 1.85 to 28.9 mg/l in the outfall points of ASP, DSP and DCL. Pre-monsoon and monsoon periods showed a comparatively lower COD concentrations in the outfall points of DSP, ASP, DCL and DPL than the other seasons. However, the result was reverse for EIPWL (Table 3).

BOD

The range of BOD concentration at the outfall point of EIPWL (4.8 to 48.6 mg/l) is remarkably higher all throughout the year than the effluent points of other industries (0.8 to 13.12 mg/l). Higher values were recorded during May to July (Table 3).

Oil and Grease

At the effluent discharge point of EIPWL the concentration of O&G ranged from 1.36 mg/l to 4.7 mg/l which is 117 to 230 % higher than the concentrations at the other outfall points. Monsoon months from June to October recorded low values than the other months (Table 3).

Spatial Variation of Different Water Quality Parameters

Due to the continuous accumulation of discharge from various industries down the middle stretch of the Tamla rivulet, the concentration of total suspended solids increased by 33% towards lower stretch. Accordingly, the high density of industries discharging heavy effluent load towards the lower stretch of Tamla rivulet (Figure 5) resulted in higher concentration of COD and BOD in the outfalls of DCL, DPL and EIPWL compared to upper stretch. However, concentration of oil and grease in the surface water did not show much spatial variation among the outfalls of studied industries due to the quality variation of the effluents.

Groundwater Quality

The Table 4 shows that there is no significance difference ($P< 0.05$) between the three different sites in terms of electrical conductivity, iron, lead, copper, phosphorus, nitrate-N, fluoride, cadmium and chromium in the drinking water from shallow tubewells. Moreover in case of total alkalinity, total hardness, chloride, sulphate, sodium, potassium and phenolic compounds, tubewell water from DSP outfall point at Court More region and Madhya Mana region although did not differ significantly ($P> 0.05$), yet the same from the Tamla village differ significantly in terms of all these parameters from the water derived from other two experimental sites. TSS, TDS, calcium, magnesium and zinc contents however, differ significantly ($P<0.05$) in water from shallow tubewells of all the three experimental sites. pH value shows that in Tamla the water is near neutral alkaline whereas in other two sites it is significantly acidic.

If compared to the setup standards (WHO 1971) it can be inferred that in the water of the shallow tubewells from the three sites, only Tamla village water shows values of pH, total $CaCO_3$, Mg within acceptable limits (Table 4). However, TSS, Cl, S, Fluoride, NO_3 was acceptable in the water from all the three sites. On the other hand, concentration of phenolic compounds was 0.07 and 0.08 mg /l which was higher than the maximum limit of 0.001 mg/ltr in Bhiringi and Madhya Mana water.

Soil Quality

Testing of soil from the three experimental sites shows (Table 5) that the soil is very slightly acidic having no significant difference in pH values ($P>0.05$) between the sites. Organic contents were insignificantly ($P>0.05$) differing in all the three sites. In terms of available nitrogen Tamla village differs significantly ($P<0.05$) from Madhya Mana, however it does not differ significantly ($P>0.05$) from that of DSP outfall point at Court More region.

Available P was also higher (8 to 10 %) in Tamla village although the difference between sites was insignificant ($P>0.05$). Cadmium content was insignificantly differing in all the sites but the chromium and manganese content was much in samples from two sites namely DSP outfall point at Court More, Bhiringi and Madhya Mana than in the soil of Tamla village ($P<0.05$) whereas in case of manganese difference between Bhiringi and Madhya Mana was insignificant ($P>0.05$).

Iron content was less in case of Tamla Village soil, and highest in Madhya Mana soil ($P<0.05$). In case of lead, copper and zinc, the highest content was in Madhya Mana and lowest in Tamla village. Tamla village has sandy loam soil with about 56.4% sand content. Other two sites have loamy soil with about 50% sand content. Available nitrogen in Tamla is however higher than the other two sites probably because N-fertilizer is added to this soil from outside.

Accumulation in Vegetables

Among all elements iron accumulation was maximum in all vegetables (Table 6). Among vegetables Spinach in all the sites has maximum iron accumulation (456 mg/kg) at Madhya Mana whereas Bottle Gourd (*Lagenaria siceraria*) has lowest iron accumulation (17.2 mg/kg) at Tamla village. Copper accumulation was maximum in cabbage (*Brassica oleracea capitala*) 2.4 mg/kg followed by Cauliflower (*Brassica oleracea botrytis*) 25 mg/kg in Madhya Mana. It was lowest in Coriander leaf (*Coriandrum sativum*) at all the three experimental sites. Magnesium accumulation does not show any uniformity among vegetables and ranged from 3-6 mg/Kg. Zinc, chromium and cadmium were <5 mg/kg in all sites. The concentration of Manganese concentration increased from 11 mg/Kg in Tamla village to 17 mg/Kg at Madhyamana region.

It is apparent from the study that iron and copper accumulation was more than maximum permissible limit of 1.0 mg/kg and 1.0 mg/kg (WHO 1990) respectively in all vegetables from the two polluted sites of Bhiringi and Madhya Mana. Statistically differences are variable (LSD Test) in different vegetables.

Landuse and Landcover Distribution

An analysis of the nature and rate of land use change in the industrial area adjoining Tamla Rivulet and its associated impact on surface water and groundwater quality is essential for a proper understanding of the present environmental problems (Krishna et al. 2001). In the present study area, mixed built-up area comprises 56.40 km^2, industrial 20.46 km^2, cropped 24.65 km^2, forest5.08km^2, waterbodies 47.54km^2, vegetated areas 17.08 km^2 and others 2.53 km^2 out of the total area 154 km^2 respectively (Figure 6).

Industrial Hazard Index

The quality of the surface water at the outfall points is categorized into five types on the basis of the calculated Industrial Hazard Index These are Excellent (0-10), Good (10 to 40), Moderate (41-80) and Poor (81-120) and very poor (>120). Of the five industries DCL and DPL fall under the category of very poor quality, DSP in the poor category, ASP and EIPWL under the good category (Figure 7). It is observed that the outfalls of DCL and DPL rated as very poor are located in the middle stretch of Tamla river and is likely to affect the adjoining vegetated and double cropped area (Figure 4) since the farmers use this polluted water for irrigation purpose. However, the adjoining settlement region is less affected as they do not directly use the vegetables grown in the affected areas. The good hazard index rating of industries ASP and EIPWL reveal adequate treatment facilities of these two industries with a minimum environmental health impact of the fringing areas. Despite the variable industrial hazard ratings in the Tamla water, the pollutant load from the studied outfall points drains towards the lower stretch of the rivulet and deposits near the confluence point with the Damodar river. This pollutant deposition leaches to some extent through the soil and contaminates the groundwater and soil of the Madhyamana region which is severely affected as evident from the groundwater and soil quality (Table 4 and 5) and the accumulation of chemicals in the vegetables (Table 6). The industrial hazard index, therefore, clearly indicates that Tamla rivulet is under severe stress and use of water from this water body for any purpose is highly deleterious environmentally and biologically. The integration of attribute database comprising the quality of Tamla water, groundwater, soil and agriculture produce of Bhiringi and Madhya Mana region with the Remote sensing and GIS study proves to be an essential tool to evaluate the impacts of industrial hazard on land use / land cover of an industry rich zone of Durgapur city in West Bengal. Similar pollution study of ground water (Asadi et al., 2007) using Remote sensing and GIS techniques has been carried out for part of Hyderabad metropolis. Spatial distribution maps of pH, TSS, COD, BOD pollution parameters have been used to demarcate the locational distribution of water pollutants in a comprehensive manner and help in suggesting surface water pollution control and remedial measures by improving the industrial effluent treatment strategies in a holistic way.

It is inferred that highly polluted Tamla rivulet is contaminating its adjoining ecosystem vehemently and has created a highly profane environmental milieu that can no longer support a high biodiversity eco-system as well as healthy human society. This calls for an urgent planning strategies and intervention from pollution control/ regulatory authorities and civic administration along with NGO intervention.

Table 1: Outfalls of different industries of Durgapur city at Tamla nullah

Name of the industry	Number of outfalls	Waste water receiving body Tamla nullah			Others	Remarks
		Upper	Middle	Lower		
Durgapur Steel Plant (DSP)	6	-	3	-	3	
Alloy Steel Plant (ASP)	6	-	6	-	-	-
Durgapur Projects Limited (DPL)	1	-		1	-	-
East India Pharmaceuticals Works Limited (EIPWL)	1	-		1	-	-
Durgapur Chemicals Limited (DCL)	1	-		1		-

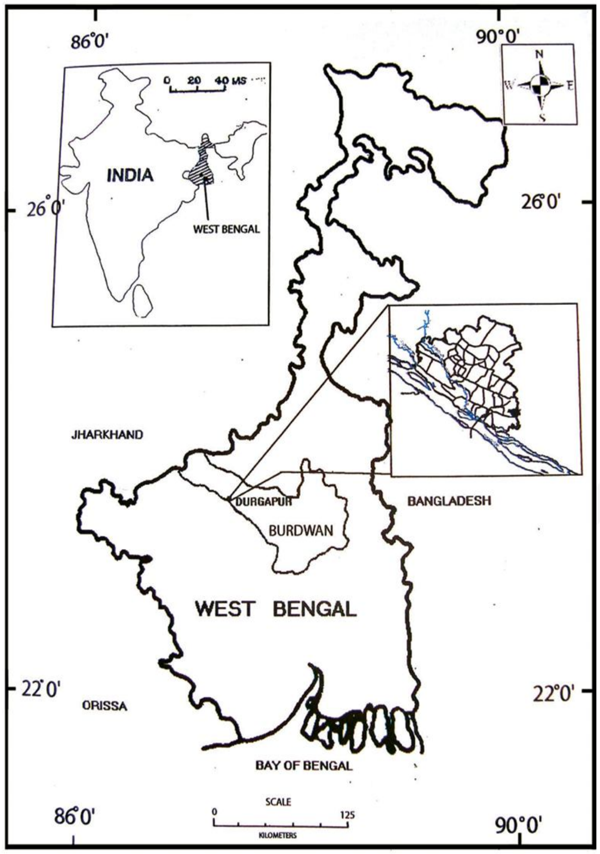


Fig. 1: Location map

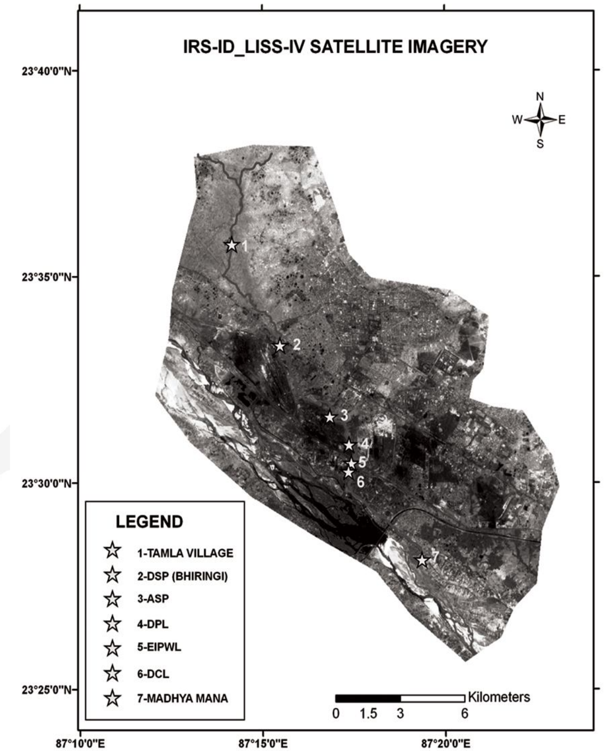


Fig. 3: Sampling sites overlaid on Satellite Imagery

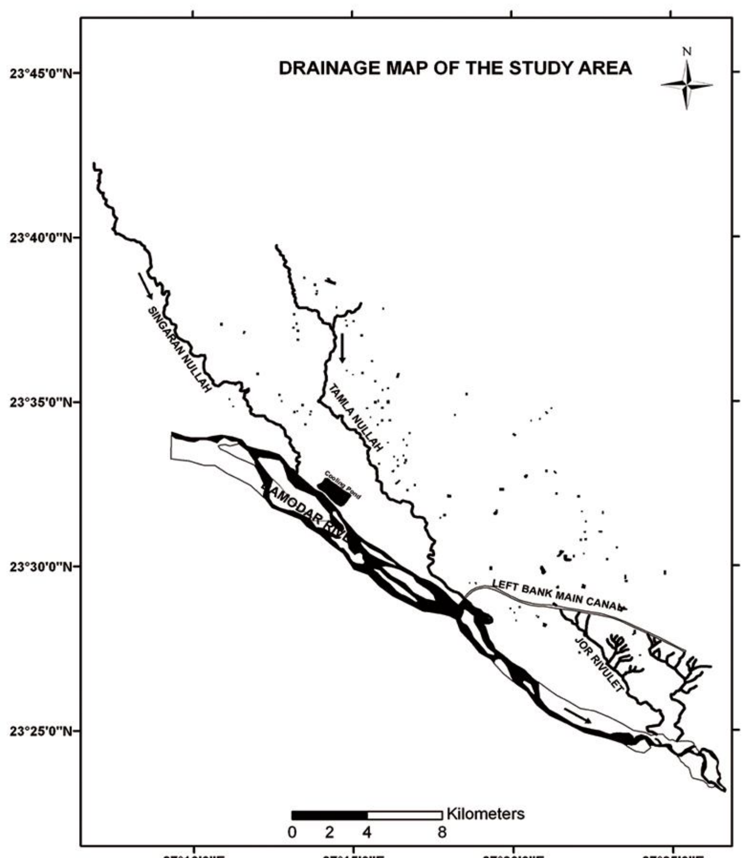


Fig. 2: Drainage Map of the study area

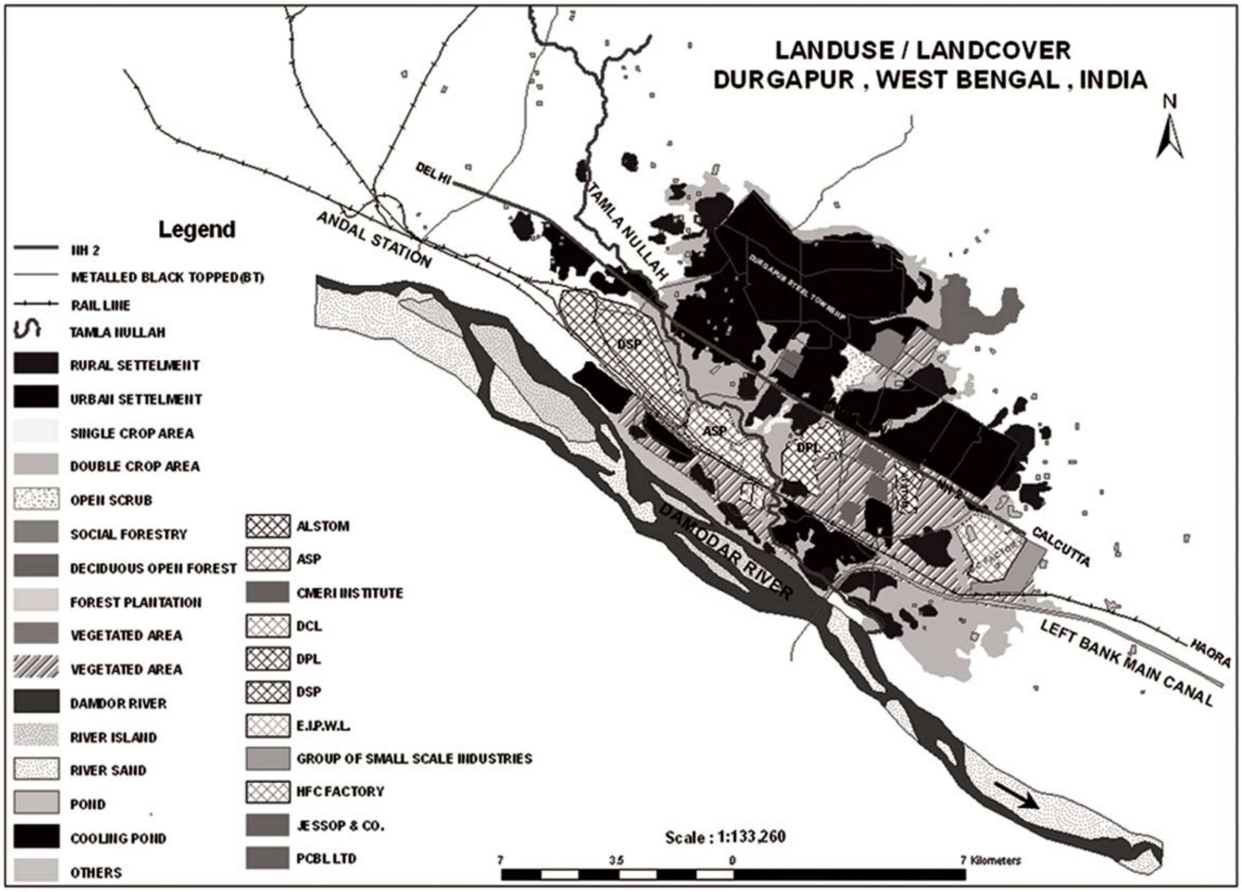


Fig. 4: Landuse/Landcover Map of the study area

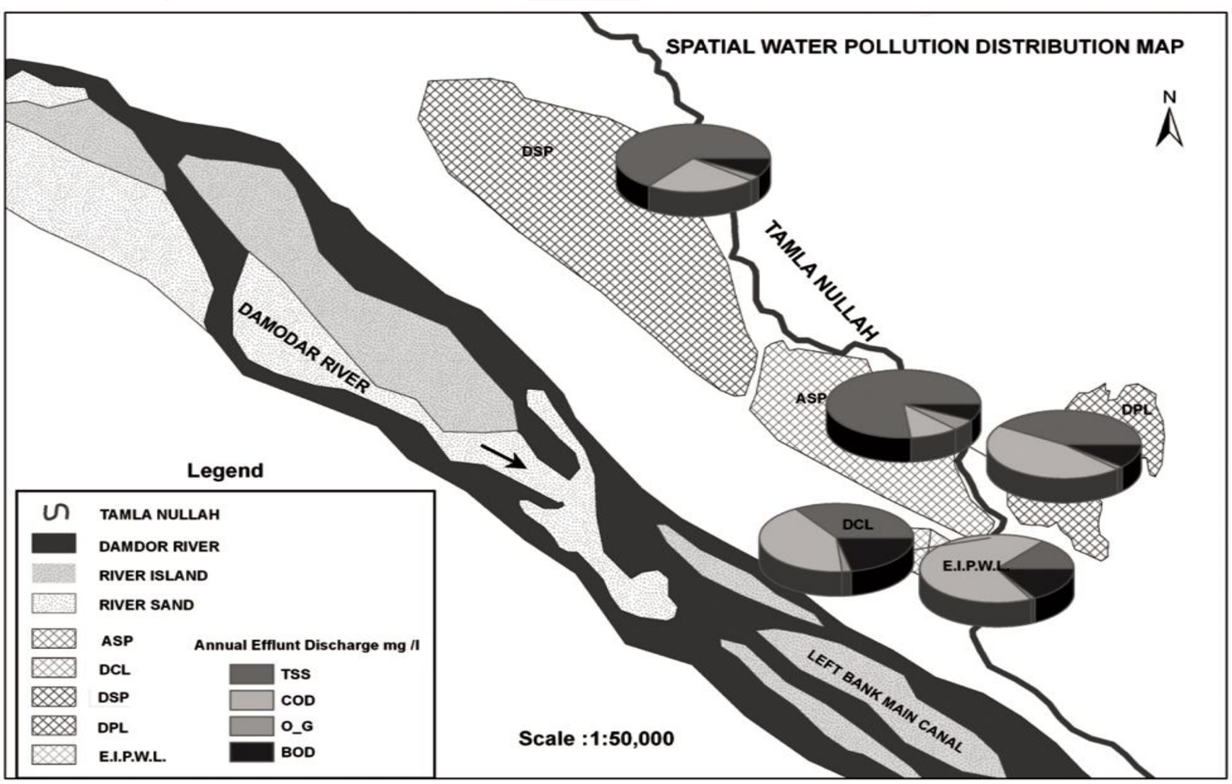


Fig. 5: Spatial and quantitative distriubution of annual effluent discharge in Tamla Nullah by the studied industries of Durgapur

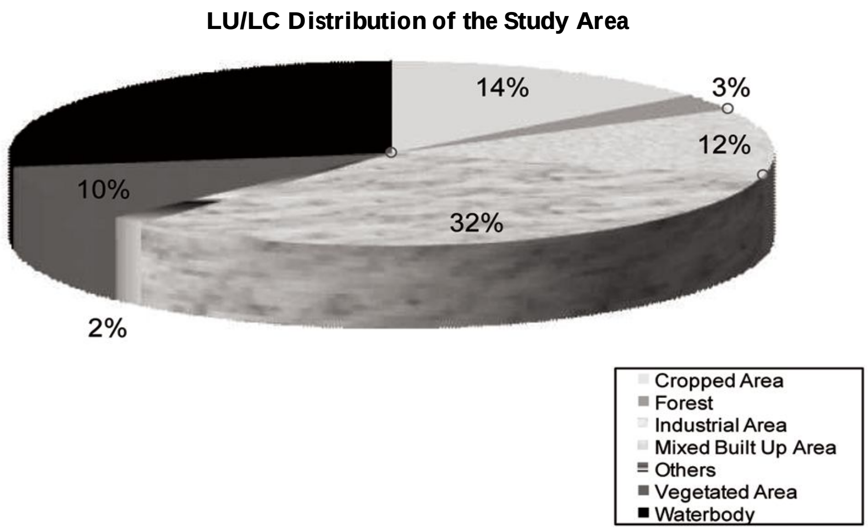


Fig. 6: Landuse / Landcover Distribution of the studied area

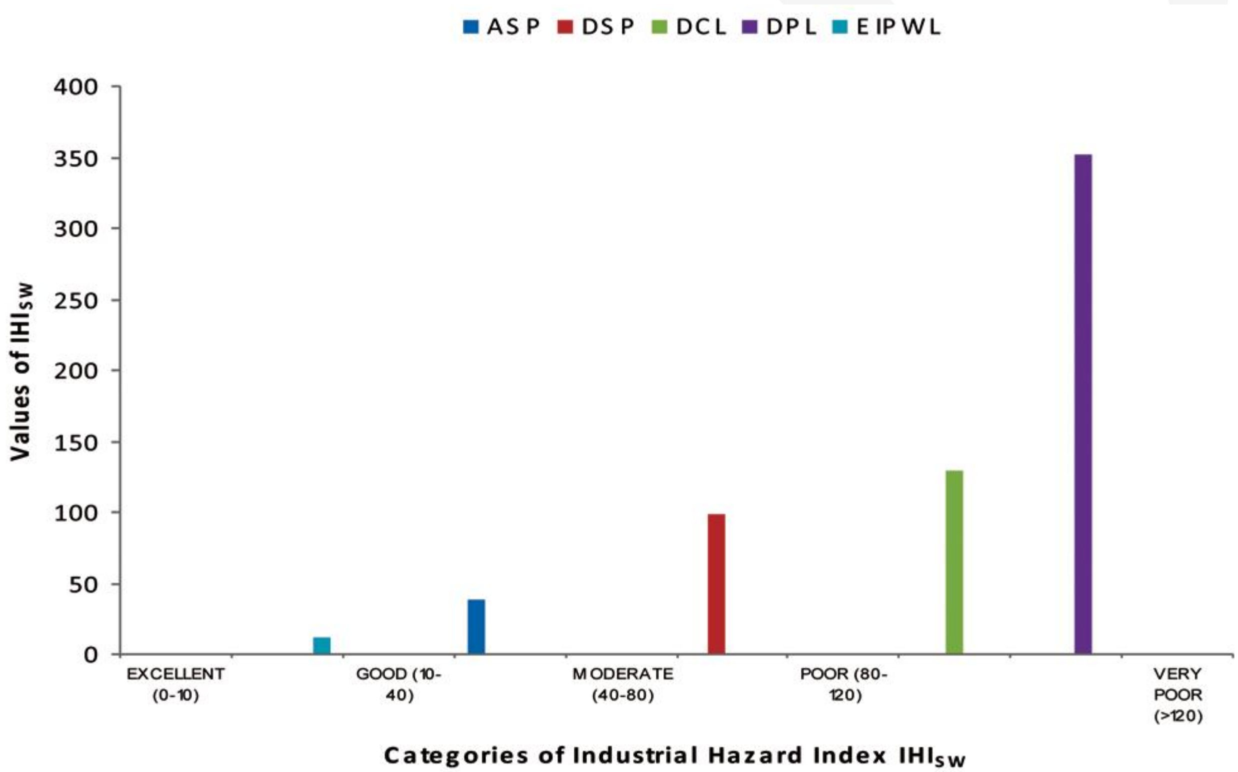


Fig. 7: Industrial hazard indices of the outfall points of the five industries studied

Table 2: Sampling sites for testing groundwater, soil, and vegetations

Segment of Tamla nullah	Names of the places	Location	Pollution status
Upper (A)	Tamla village	North-western part of the Durgapur city	No outfalls, Unpolluted
Middle (B)	Bhiringi Municipal area	Immediate vicinity of the Durgapur Steel Plant and other industries	Outfalls, Polluted with effluent discharge load
Lower (C)	Madhyamana	Eastern vicinity of Durgapur, confluence of Tamla nullah and river Damodar	No outfalls, Polluted with entire downstream effluent load

Table 3: Seasonal variation of surface water quality parameters in the selected outfalls of different industries

Selected outfalls of different industries	Mean Concentration mg/Ltrs.													
	Parameters	**Std. values**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
DSP	pH	7.0-8.5	8.0	7.50	7.80	7.60	7.40	7.8	7.40	8.0	7.15	7.94	7.0	6.38
	TSS	100	16.3	20.3	50.7	13.7	61.7	50.8	32.4	13.3	35.5	35.9	32	58.4
	COD	250	8.3	8.2	16.0	16.0	18.5	15.2	13.5	7.0	28.9	28	16.6	*16*
	BOD	30	3.8	4.7	2.6	1.8	1.5	1.23	3.0	5.74	8.5	*6.0*	2.15	3.4
	O&G	10	1.6	1.3	2.0	1.0	1.2	0.86	0.7	1.0	1.25	1.3	1.2	1.7
ASP	pH	7.0-8.5	7.57	7.20	7.30	6.04	6.5	7.54	7.0	7.00	7.04	7.35	7.6	7.45
	TSS	100	12.4	17.0	28.4	5.6	15.0	11.6	22.0	11.6	16.0	16.2	16.7	14.8
	COD	250	1.85	2.8	4.0	1.44	1.8	1.0	3.5	5.2	1.13	2.25	2.9	2.12
	BOD	30	0.8	1.36	1.78	0.76	1.0	0.98	1.11	2.36	0.8	1.2	1.13	1.06
	O&G	10	0.4	1.5	0.6	1.64	0.73	1.0	0.65	0.55	0.36	1.2	1.5	1.1
EIPWL	pH	7.0-8.5	8.9	8.9	7.8	7.5	8.6	8.1	7.6	7.8	8.1	8.6	8.65	8.8
	TSS	100	15.3	18	22	6.4	25.0	31.7	52.6	58	26.34	16	19.25	23.2
	COD	250	96.03	150.92	187	216.4	167.9	227.8	177.4	127.6	136	167.5	105.2	116.4
	BOD	30	21.2	47.5	27.3	18.34	48.6	61.6	39.2	25	23.5	4.8	19.2	30.2
	O&G	10	2.11	1.36	1.44	3.32	3.66	2	1.39	2.23	1.99	1.32	3.31	4.7
DCL	pH	7.0-8.5	8.2	7.36	7.8	7.9	7.1	8.3	8.1	8.1	7.43	8.21	7.67	8.7
	TSS	100	11.5	10.2	11.0	12.5	36	20.8	10.6	12	11.3	10.5	12.6	27.3
	COD	250	13.03	16.1	16.6	19.5	21.6	27.8	14.2	13.8	13.42	16.5	17.3	14.7
	BOD	30	7.2	10.4	11.3	12.4	9.5	15.9	11.3	9.2	6.4	5.8	2.2	3.6
	O&G	10	1.14	1.28	1.36	1.01	1.07	1.21	1.05	0.87	1.02	1.37	1.25	1.17
DPL	pH	7.0-8.5	6.8	5.9	7.2	7.4	7.6	8.1	7.5	6.5	7.4	8.1	8.9	7.2
	TSS	100	25.6	30.13	13.7	27.5	20.5	18.6	222.4	35.2	42.5	56.3	22.4	43
	COD	250	43.4	81.4	34.8	48.2	46	39.3	27	53.5	47.2	56.8	76.3	51.7
	BOD	30	12.5	13.12	3.71	5.0	10.4	13.39	3.9	6.8	9.2	12.5	11.5	11.7
	O&G	10	1.23	3.5	1.22	2.0	2.16	1.14	0.37	0.96	1.11	1.25	1.02	0.8

Table 4: Analysis of ground water of the three experimental sites (Data: Mean ± SE)

Sl. No.	Parameters	Tamla Village	DSP Out fall Point Court More, Bhiringi	Madhya Mana	LSD	ISI Standard
1	pH Value	<0.1± 0.3	6.24 ± 0.3	6.33 ± 1.4	0.7	6.5-9.2
2.	Electrical Conductivity (µs/cm)	289 ± 4.3	287 ± 7.4	290.0 ± 8.3	5.9	
3.	TSS (mg/L)	0.7± 0.3	15.0 ± 4.3	25.0 ± 3.2	3.7	
4.	TDS (mg/l)	16.0 ± 2.4	153.0 ± 18.9	186.0 ± 17.2	11.4	1500.0
5	Total Alkalinity (mg/L CaCO3)	32.0 ± 4.9	103.0 ± 6.4	115.0 ± 14 .7	17.3	
6	Total Hardness (mg/L CaCO3)	39.0 ± 3.1	124.3 ± 11.2	114.0 ± 17.9	14.7	
7	Chloride (Cl mg/L)	2.4±1.2	16.1 ± 2.4	20.0 ± 3.7	4.3	1000
8	Sulphate (SO 4mg/L)	4.2± 0.9	20.3 ± 3.2	24.8 ± 5.9	5.1	400
9	Calcium Ca mg/L)	6.1 ± 2.1	23.9 ± 3.2	32.1 ± 5. 8	5.2	200
10	Magnesium (Mg mg/L)	1.4 ± 1.0	10.2 ± 2.0	15.6 ± 3.1	2.7	100
11	Iron (Fe mg/L)	0.9 ± 0.1	1.2 ± 0.2	1.2 ± 0.2	0.2	
12	Lead (Pb mg/L)	<0.01	<0.01	<0.01	-	
13	Copper (Cu Mg/L)	0.02 ± 0.0	0.03 ± 0.01	0.03 ± 0.01	0.01	
14	Zinc (Zn mg/L)	0.001 ± 0.0	0.82 ± 0.3	0.87 ± 0.02	0.02	
15	Sodium (Na mg/L)	0.9 ± 0.01	7.4 ± 1.0	9.0 ± 1.4	1.9	
16	Potassium (K mg/L)	0.03 ± 0.01	1.0 ± 0.01	1.0 ± 0.2	0.01	
17	Phosphorus (P mg/L)	<0.2	<0.2	<0.2	-	
18	Nitrate (N mg/L)	0.07 ± 0.01	0.02 ± 0.01	0.05 ± 0.02	0.02	45
19	Flouride (F mg/L)	<0.1			-	1.5
20	Phenolic Compound (mg/l)	0.001 ± 0.0	0.08 ± 0.01	0.07 ± 0.02	0.01	
21	Cadmium (Cd mg/L)	<0.01	<0.01	<0.01	-	
22	Chromium (mg/L)	<0.01	<0.01	<0.01	-	

Table 5: Physico-chemical analysis of soil of the three experimental sites (Mean ± 1 SE)

Sl	Parameters	Tamla Village	DSP Out fall Point Court More, Bhiringi	Madhya Mana	LSD
1	pH Value (1 : 2.5)	6.9 ± 0.2	6.32 ± 0.4	6.47 ± 0.7	0.8
2	Particle S ize				-
	Clay %	20.2 ± 2.1	22.2 ± 3.1	20.2 ± 3.4	
	Slit %	23.4 ± 3.9	27.6 ± 2.1	28.5 ± 5.3	
	Sand%	56.4 ± 5.3	50.2 ± 4.4	49.5 ± 6.9	
3	Textural Class	Sandy Loam	Loam	Loam	-
4	Organic Carbon (%)	1.4 ± 0.2	1.3 ± 0.3	1.3 ± 0.2	0.3
5	Available Nitrogen (mg/kg)	68.7 ± 8.9	59.2 ± 9.4	57.75 ± 9.2	9.9
6	Available Phosphorus (mg/kg)	130.3 ± 12.8	118.0 ± 16.2	115.3 ± 18.7	12.3
7	Cadmium (Cd mg/kg)	<5.0	<5.0	<5.0	-
8	Chromium (Cr mg/kg)	4.6 ± 1.7	24.0 ± 6.2	32.0 ± 4.9	5.4
9	Manganese (Mn mg/kg)	17.4 ± 3.2	149.2 ± 2 1.0	174.0 ± 16.4	28.2
10	Iron (Fe mg/kg)	22.9 ± 4.2	27.2 ± 4.9	32.5 ± 4.3	6.9
11	Lead (Pb mg/kg)	3.1 ± 1.2	14.2 ± 4.9	16.0 ± 2.4	4.3
12	Copper (Cu mg/kg)	6.1 ± 1.2	29.0 ± 2.4	32.0 ± 3.2	4.3
13	Zinc (Zn mg/kg)	3.1 ± 1.2	15.2 ± 3.2	17.0 ± 3.8	5.4

Table 6: Mineral matter concentration in different vegetables at the three experimental sites (Data : Mean ± 1 SE)

Sl	Mineral Matters	Tamla Village					DSP Out fall Point Court More, Bhiringi					Madhya Mana				
		Brinjal	Palak	Cabbage	Chilli	Cauliflower	Brinjal	Palak	Cabbage	Chilli	Cauliflower	Brinjal	Palak	Cabbage	Chilli	Cauliflower
1	Iron (Fe mg/kg)	24.2 ± 3.4	170 ± 24.0	100.0 ± 18.0	80.6 ± 11.1	120.0 ± 11.0	31.4 ± 2.1	195.0 ± 20.0	118.0 ± 12.0	96.3 ± 12.1	125.0 ± 12.0	36.1 ± 9.2	456.0 ± 30.0	407.4 ± 22.0	113.4 ± 23.1	392.0 ± 18.7
2	Copper (Cu mg/kg)	1.1 ± 1.0	1.1 ± 0.4	1.0 ± 0.2	1.6 ± 0.3	1.0 ± 0.2	3.4 ± 1.0	9.3 ± 2.3	23.1 ± 3.6	9.3 ±2.4	20.0 ± 3.4	4.3 ± 0.1	16.3 ± 3.2	28.4 ± 9.2	13.2 ± 3.6	25.0 ± 3.8
3	Calcium Ca mg/kg)	5.0 ± 1.4	7.2 ± 1.9	17.0 ± 3.0	6.4 ± 2.3	15.0 ± 3.1	5.3 ± 1.4	10.4 ± 2.1	9.2 ± 2.3	7.9 ± 2.1	10.0 ± 2.1	6.2 ± 2.9	8.4 ± 2.7	13.3 ± 3.1	9.6 ± 2.1	20.0 ± 3.1
4	Magnesium (Mg mg/kg)	<5.0	7.9 ± 2.2	7.2 ± 1.2	4.0 ± 1.3	6.0 ± 1.4	<5.0	8.4 ± 2.4	3.4 ± 1.2	5.4 ± 2.1	3.0 ± 1.3	<5.0	3.7 ± 1.1	3.7 ± 1.3	12.5 ±3.1	4.0 ± 1.0
5	Zinc (Zn mg/kg)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
6	Chromium (Cr mg/kg)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
7	Cadmium (Cd mg/kg)1	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
8	Manganese (Mn mg/kg)	3.2 ± 1.0	5.9 ± 0.9	7.2 ± 1.3	<5.0	11.0 ± 3.1	5.2 ± 0.4	8.0 ± 1.0	12.0 ± 1.3	<5.0	14.0 ± 2.4	6.9 ± 2.1	15.0 ± 2.0	17.3 ± 3.4	<5.0	17.0 ± 4.9

Conclusion

In the study area human populations and ecological receptors are in continuous contact with industrial discharges because they are present in air, water, soil and food. These links manifest themselves through their effect on human health and ecology. Therefore, the link demands exact identification of the causes for formulation of sound environmental planning thereby necessitating studies and analysis of environmental hazards of the area. To provide a comprehensive but easy to use tool in the assessment and evaluation of water quality in this industrially polluted area, the concept of industrial hazard index (IHI) has been used. This index coupled with available pollution data after integration spatially in thematic maps prepared by interpretation of satellite imagery using a computer based analytical system of GIS will help in the environment planning and decision support system of the study area. The study results in Industrial hazard index mediated spatial demarcation of pollution stretch on GIS platform for stringent future environmental amendments.

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