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IMPACT OF INDUSTRIAL WASTE ON GROUND WATER IN AND AROUND BARI BRAHMNA INDUSTRIAL AREA, SAMBA DISTRICT, JAMMU AND KASHMIR, INDIA

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ABSTRACT
Ground water quality in the areas surrounding industrial zones is a subject of major concern owing to nearing proximity of residential zones. This paper presents quality of water samples from tube wells as well as open wells in and around the industrial zone of Bari Brahmana in order to find out the magnitude of contamination of ground water by the industrial waste. Twenty eight groundwater samples collected from the study during pre monsoon and post monsoon seasons of 2010. Twenty chemical parameters including pH, Electric Conductivity (EC), Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Bi carbonate (HCO_3), Sulfate (SO_4), Nitrate (NO_3), Fluoride (F), Chloride (Cl), Total Hardness and heavy metals like Manganese (Mn), Zinc (Zn), Lead (Pb), Iron (Fe), Copper (Cu), Nickel (Ni), Cadmium (Cd) and Chromium (Cr) were analyzed. The results were compared with standard guidelines of BIS. The study reported the concentration of some heavy metals in the ground water samples exceeded the permissible limit prescribed by Bureau of Indian Standards for drinking purpose. Thus, there is a significant risk to the population living near and downstream of the Industrial Estate, Bari Brahmana, given the toxicity of these metals and the fact that for many, hand pumps, dug wells and tube wells are the only sources of their water supply in this area.

KEYWORDS: Kandi, Ground water, Aquifer, BIS, Industrial waste.

INTRODUCTION
Groundwater is a globally important and valuable renewable resource for human life and economic development. Waste includes all the discarded solid materials from commercial, municipal, industrial and agricultural activities (Afolayan *et al*., 2012; Christopher *et al*., 2011). Groundwater pollution is mainly due to the process of industrialization and urbanization that has progressively developed over time without any regard for environmental consequences. In recent times, the impact of leachate on groundwater and other water resources has attracted a lot of attention because of its overwhelming environmental significance (Longe and Balogun, 2010; Mohd Raihan *et al*., 2011). Leachate migration from wastes sites or landfills and the release of pollutants from sediments (under certain conditions) pose a high risk to groundwater resource if not adequately managed. Waste management has become increasingly complex due to the increase in human population, industrial and technological revolutions and the processes that control the fate of wastes in the soil is complex and many of them are poorly understood. Issues such as nutrients release rate and other chemicals, leaching of nutrients, metals through macro pores as suspended solids and sludge organic matter on the sorption degradation are often not understood by many (Durfer and Backer, 1964; Loizidou and Kapetanios, 1993; Afolayan *et al*., 2012). Leaching of hydrophobic organics and long term bioavailability and fate of metals fixed by soil organic matter needed to be studied to have a better approach in handling groundwater pollution. Toxic chemicals that have high concentration of nitrate and derived from waste in the soil can filter through a dump and contaminate both ground and surface water (Adekunle *et al*., 2007; Esmail *et al*., 2009; Jhamnani and Singh, 2009).

The volume of waste generated in Bari Brahmna industrial area has increased significantly over time because of increase in population, industrial and economic development. The objective of the present study therefore was to assess the magnitude of contamination of ground water by the industrial waste.

Study Area
Bari Brahmna is emerging as a leading industrial estate in Jammu and Kashmir State. It is about 12 km from Jammu in the south-east of Jammu City on Jammu- Pathankot National Highway. At present about 700 industries, manufacturing units of plastics, textiles, fertilizers, transformers, fats and oils, distilleries, detergents, papers, medicines, steel and several other products exist in this industrial estate.

The study area lies between 32° 35' & 33° 42' north Latitude and 74° 49' & 75° 00' east longitude falling in the Toposheet No. 43 L/14. It is located at the foothills of the Siwalik Hills and has an altitude varying between 320-350 m above the mean sea level. Ballol Nallah and Bari Khad nallah are the two seasonal nallahs that drain the area. These two nallahs are boulder laden and have broad shallow channels, having water only for short time after the rains. After traveling a distance of about 4 kms in the south-west direction, both of these join river Tawi near Lalyal village.

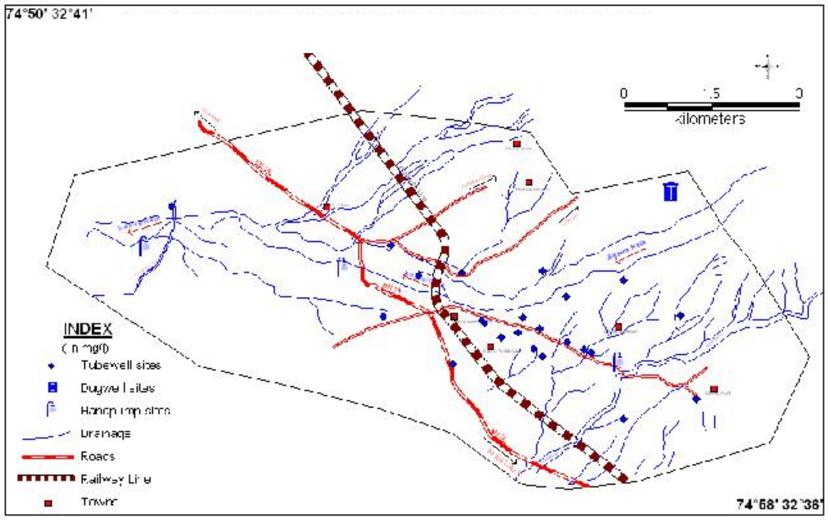

FIGURE 1: Location Map of the study area and sampling sites
Hydrogeology of the Study Area

Geologically, the study area falls in Kandi belt (Bhabar) ranging in age from Recent to Sub Recent. The sediments of Kandi have been laid down by descending rivers by shedding their loads. These sediments comprise of boulders, pebbles, gravels, sand and clay in highly mixed fashion (Vijay and Omkar, NIH).

The Kandi belt, as comprised of the reworked sediments of the older rocks, is highly porous in nature, having clay layers in between. Thus, ground water occurs under unconfined to semi-confined conditions at very deeper levels in these areas. The lithology of sediments and nature of the aquifer influences the scale of the ground water contamination. Therefore, this highly porous aquifer having only modest permeability, allows the flow of groundwater easy and relatively rapid, increasing the possibility of widely dispersed contamination in a given time than where flow is intergranular. The hydrogeological data reveals that depth of the tube wells in the study area ranges between 75 m below ground level (bgl) and 125 m bgl. During pre-monsoon survey, depth to water level ranges between 3.50 m bgl and 28 m bgl, whereas in post monsoon depth to water level ranges between 2 m bgl and 26 m bgl. The yield of the tubewells during pre-monsoon ranges between 50 litres per minute (lpm) and 480 lpm and in post-monsoon between 100 lpm and 580 lpm.

METHODOLOGY

To assess the impact of industrial pollution on ground water quality, both before and after monsoon season, sampling of ground water was done from four dug wells and twenty four deep tube wells in and around the study area (Figure 1) during May-June 2010 and October-November 2010. These samples were analysed for their physical and chemical characteristics as per standard procedure for chemical analysis. Electrical Conductivity (EC) and pH were measured in the field using digital meters immediately after sampling. Sampling bottles of one litre capacity were used for collecting water samples. Samples from the production tube were collected after running the well for about 5 minutes. Two sets of water samples were collected of which one was acidified by adding two milliliters of HNO_3 (A. R Grade). The accuracy of the chemical analysis was verified by calculating ion balance errors where, the errors were generally around 5%. The heavy metal analysis was carried out by Atomic Absorption Spectrophotometer (AAS). The results were compared with the drinking water standards of the Bureau of Indian Standards (BIS, 2009).

RESULTS & DISCUSSION

Geochemistry

Shallow Aquifers

The analytical results of the water samples reveals that the shallow ground water of the area is alkaline in nature and during post monsoon season the alkalinity is more compared to pre-monsoon season. The preferential order of major ions is $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ and $HCO^{-}_3 > Cl^{-} > NO_3^{-} > SO^{2-}_4$. Calcium and magnesium are the dominant cations and bicarbonate is the dominant anion in this region. The ranges of water quality parameters of the shallow aquifer samples of study area during pre-monsoon and post-monsoon seasons were compared with the BIS Limits for drinking water and are given in table 1. The concentrations of ions, such as Ca^{2+}, Mg^{2+}, SO_4^{2-} and F^{-} are within the maximum permissible limits for drinking except for one sample for NO_3^{-} in the post monsoon season and one for Mg^{2+} in the pre monsoon season in shallow aquifers.

TABLE 1: Water Quality Parameters of Shallow Aquifers of Study Area

Water Quality Parameters	BIS Limits		Pre monsoon		Post monsoon	
	Desirable	Permissible	Min	Max	Min	Max
pH	6.5-8.5	No relaxation	7.48	8.49	7.25	7.50
EC µmhos/cm at 25°C	500	2000	440	1040	460	990
Carbonate (mg/l)	-	-	00	06	00	00
Bi carbonate (mg/l)	-	-	195	350	299	476
Chloride (mg/l)	250	1000	11	28	7.1	60
Nitrate (mg/l)	45	No relaxation	12	26	Tr	78
Fluoride (mg/l)	1.0	1.5	0.02	0.15	Tr	0.31
Sulphate (mg/l)	200	400	04	12	5.2	14
Calcium (mg/l)	75	200	24	84	90	160
Magnesium (mg/l)	30	No relaxation	16	42	7.2	15
Sodium (mg/l)	-	-	8.2	28	5.0	60
Potassium (mg/l)	-	-	0.9	1.9	0.4	5.1
Total Hardness as $CaCO_3$ (mg/l)	200	600	215	295	265	460

Deep Aquifers

In the study area, ground water in deeper aquifers is mildly alkaline in nature. Two tube wells have reported pH more than 8.25. During both the seasons all the samples collected and analyzed from deep aquifer have all the parameters well within the permissible limits of BIS, except for Mg^{2+} whose concentration is although less in comparison to calcium but in 4 samples its concentration is more than MPL in the pre monsoon season. Potassium concentration in study area is generally low in deeper aquifers. The order of dominance for cations and anions is $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ and $HCO^{-}_{3} > Cl^{-} > SO^{2-}_{4} > NO_3^{-}$ respectively. The dominance of Ca^{2+} and Mg^{2+} in the study area is the cause of hardness of water. The minimum and maximum ranges of water quality parameters of the deep aquifer samples of study area during pre-monsoon and post-monsoon seasons were compared with the BIS Limits for drinking water and are given in table 2.

TABLE 2: Water Quality Parameters of Deep Aquifers of Study Area

Parameters	BIS Limits		Pre monsoon		Post monsoon	
	Desirable	Permissible	Min	Max	Min	Max
pH	6.5-8.5	No relaxation	7.01	8.49	7.30	8.39
EC µmhos/cm at 25°C	500	2000	320	1540	360	1080
CO_3 (mg/l)	-	-	00	Traces	00	12
HCO_3 (mg/l)	-	-	165	397	159	427
Cl^- (mg/l)	250	1000	7.1	295	3.6	224
NO_3^- (mg/l)	45	No relaxation	6.3	38	6.5	35
F^- (mg/l)	1.0	1.5	0.01	0.23	Trace	0.45
SO_4^{2-} (mg/l)	200	400	Traces	190	Trace	160
Ca^{2+} (mg/l)	75	200	24	234	62	194
Mg^{2+} (mg/l)	30	No relaxation	3.6	84	4.8	28
Na^+ (mg/l)	-	-	09	67	7.60	79
K^+ (mg/l)	-	-	0.9	2.1	0.5	1.7
Total Hardness as $CaCO_3$ (mg/l)	200	600	165	700	200	570

Total Hardness

Hardness of water is the capacity to neutralize soap and is caused by carbonates and bicarbonates of calcium, magnesium. In both Shallow as well as deep aquifers, due to high concentration of calcium and magnesium ions, ground water is hard to very hard type, table 3.

TABLE 3: Classification of Hardness (Shallow Ground Water)

Source	Number of Samples	Season	Soft 0-60 mg/l	Moderate 61-120 mg/l	Hard 121-180 mg/l	Very Hard > 180 mg/l
Shallow	4	Pre monsoon	00	00	00	04 (100%)
Aquifer	4	Post monsoon	00	00	00	04 (100%)
Deep	24	Pre monsoon	00	00	02 (8%)	22 (92%)
Aquifer	24	Post monsoon	00	00	00	24 (100%)

TYPE OF WATER

Shallow Aquifer

All samples of the study area collected in pre-monsoon are of mixed type water. About 50% of samples are of Ca-Mg-HCO_3 type. One sample is of Mg-Na-Ca-HCO_3 type, and one water sample is associated with salts of strong acid *i.e*. Cl, (Ca-Na-HCO_3-Cl). During post monsoon season, 50 % water samples are of Ca-HCO_3 type and rest of 50% is of mixed type *i.e*., Ca-Na-HCO_3.

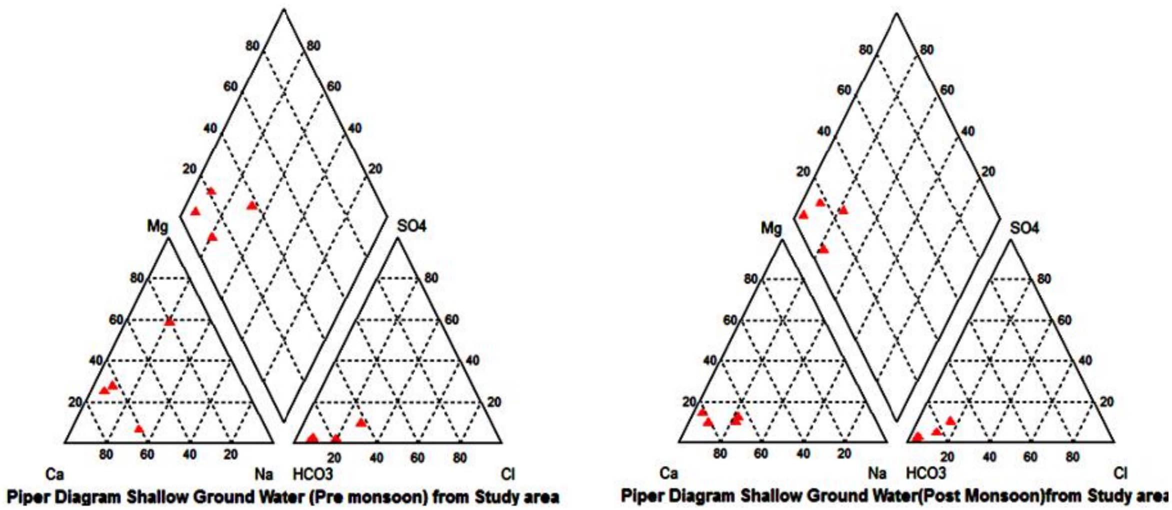

FIGURE 2: Hill Piper Diagrams of Shallow Aquifers of the Study Area

Deep Aquifer

During pre-monsoon season, about 20.8% of samples are found to have Ca-HCO_3 type of water. In 37.5% of samples Ca-Mg are dominating among all cations and bi carbonate among anions and forms Ca-Mg-HCO_3 or Mg-Ca-HCO_3. About 12.5% of samples have combination of alkali and alkaline earth elements and salts of strong acids (Ca-Na-HCO_3-Cl). Rest 29.2 % samples of study area have mixed type of water. During post monsoon season, more than 52% of samples are of Ca-HCO_3 type and 17.4% are of Ca-Mg-HCO_3 type. Rest 30.6% of samples are of mixed type with alkali alkaline earth elements and combination of salts of strong acids Cl and SO_4 and some with weak acid of HCO_3.

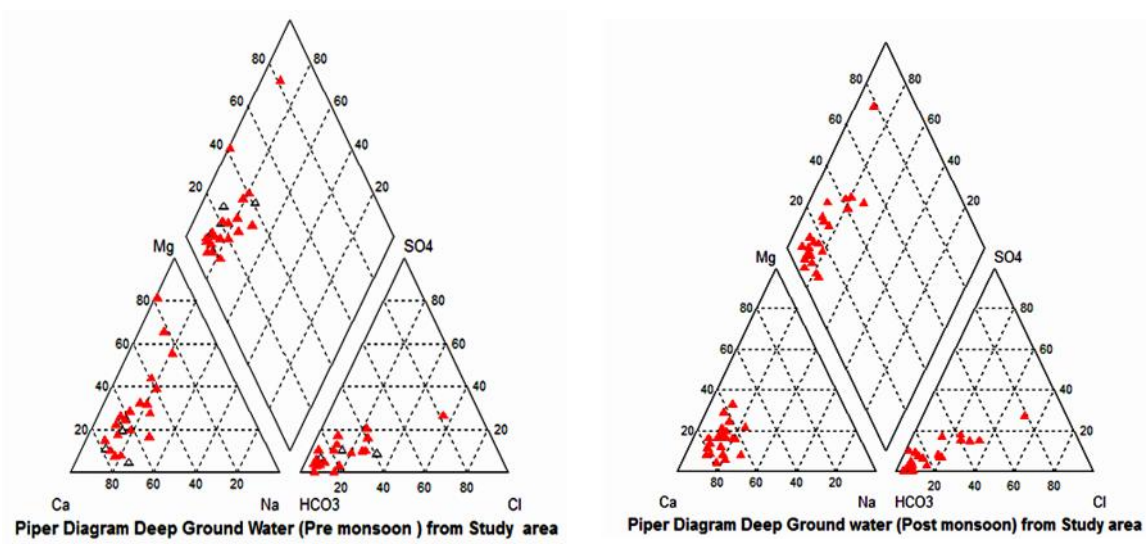

FIGURE 3: Hill Piper Diagrams of Deeper Aquifers of the Study Area

Effect of Heavy Metals

To assess the effect of heavy metals on the ground water from the shallow and deeper aquifers of the study area, their results were compared with the maximum contaminant level specified by the Bureau of Indian Standards is given in table 4.

TABLE 4: Ranges of Heavy Metals in Ground Water of Study Area

Heavy Metals	BIS Limits		(Pre-Monsoon)				(Post-Monsoon)			
	Desirable	Permissible	Shallow		Deep		Shallow		Deep	
			Min	Max	Min	Max	Min	Max	Min	Max
Fe (mg/l)	0.3	No relaxation	0.4	2.36	Traces	2.4	0.14	1.43	Traces	0.95
Zn (mg/l)	5	15	0.413	2.698	0.1	2.06	0.499	2.53	n d	1.144
Mn (mg/l)	0.1	0.3	0.017	1.34	0.005	0.65	0.031	0.551	0.014	0.845
Cr (mg/l)	0.05	No relaxation	nd	0.011	nd	0.021	0.022	0.033	n d	0.038
Cu (mg/l)	0.05	1.5	0.004	0.023	nd	0.21	n d	0.014	n d	0.019
Cd (mg/l)	0.003	No relaxation	0.005	0.006	0.002	0.007	n d	0.001	n d	0.022
Pb (mg/l)	0.01	No relaxation	0.018	0.032	nd	0.097	0.022	0.066	0.003	0.066
Ni (mg/l)	0.02	No relaxation	0.061	0.088	0.01	0.910	0.021	0.055	0.019	0.58

The concentrations of Copper, Zinc and Chromium for all the samples meet the maximum permissible limit (MPL) of BIS. The concentration of Iron, Manganese, Nickel, Cadmium and Lead were found more than MPL of BIS in pre as well as post-monsoon seasons. The iron and steel manufacturing units are the main polluting source of Manganese. Its concentration is found more than MPL of BIS in one sample during pre-monsoon and in three samples during post-monsoon season. Nickel and Cadmium are released in atmosphere from iron and steel furnaces or from effluents of electroplating wastes, nickel and steel alloy industries, dyes and textiles and nickel-cadmium batteries. Lead salts are used as anti knocking compounds in gasoline engines. It is also released by smelting operations. Effluents of industries of paints, batteries, printing and dyeing are the sources of lead in ground water. The locations of sampling sites from where concentration of heavy metals like Iron, Manganese, Lead and Nickel are found to be more than maximum permissible limit (MPL) are shown in figure 4 and 5.

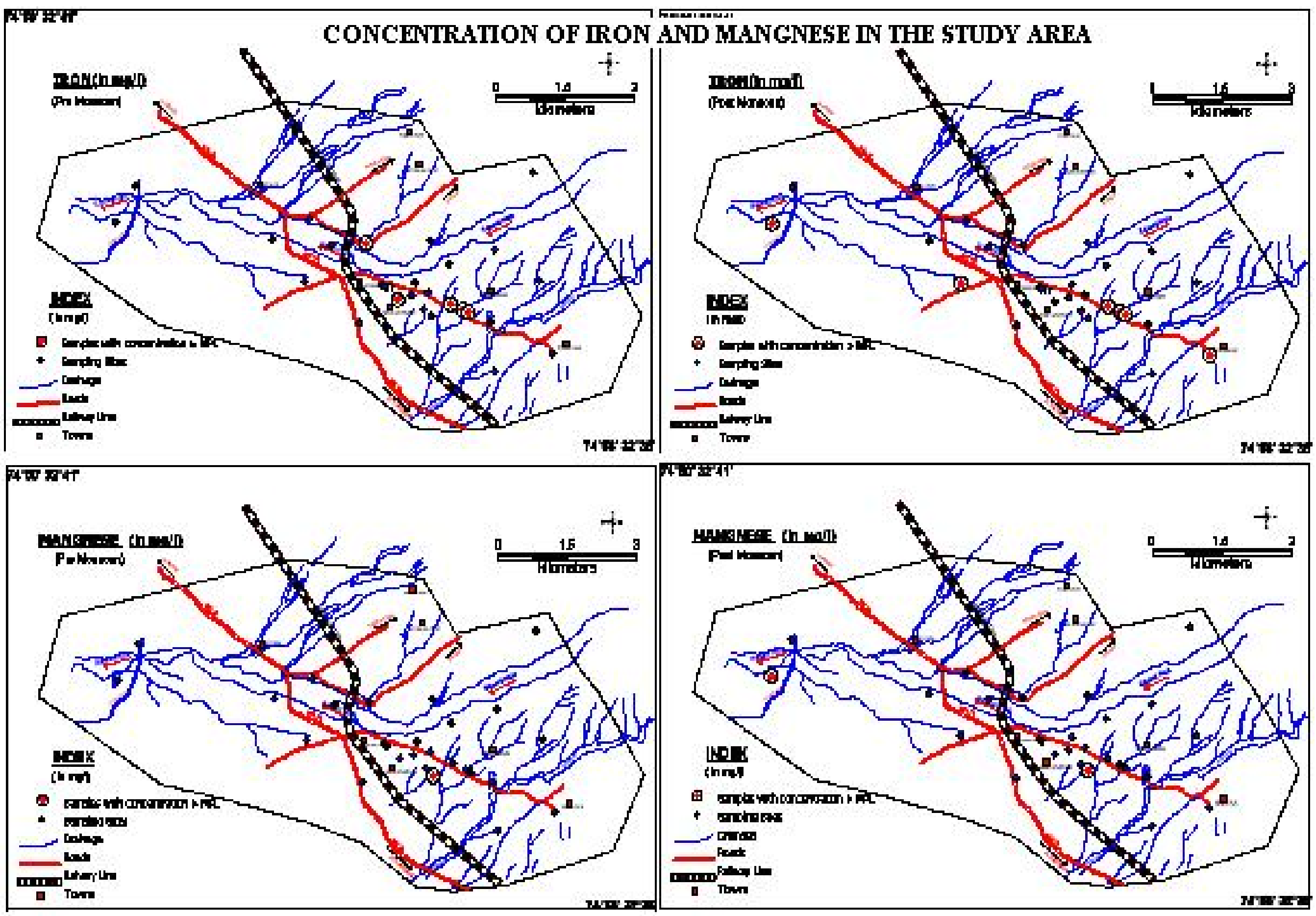

FIGURE 4: Point Values of Iron and Manganese in the Study Area

To know the spread of the heavy metals in the ground water of the study area, their mean and standard deviations are calculated. A low Standard Deviation (SD) indicates that the data points tend to be very close to the mean and high SD indicates their spread over a large range of values. The Mean and Standard Deviation of heavy metals in water samples from shallow and deeper aquifers during pre-monsoon and post-monsoon seasons is given in table 5.

TABLE 5: Standard Deviation of heavy metals in ground water of Study Area

Variables	Mean ± Standard Deviation (Pre Monsoon)		Mean ± Standard Deviation (Post Monsoon)	
	Shallow	Deep	Shallow	Deep
Fe (mg/l)	1.380 ±0.98	0.0537 ±0.733	1.38 ± 0.98	0.537 ±0.733
Zn (mg/l)	1.057 ±1.1006	0.492 ±0.389	1.122 ±0.961	0.373 ±0.320
Mn (mg/l)	0.351 ±0.659	0.062 ±0.131	0.218 ±0.232	0.103 ±0.191
Cr (mg/l)	0.005 ±0.0045	0.006 ±0.0053	0.028 ±0.0063	0.023 ±0.007
Cu (mg/l)	0.010 ±0.009	0.032 ±0.0608	0.0086 ±0.0061	0.010 ±0.008
Cd (mg/l)	0.006 ±0.0005	0.004 ±0.0011	0.001 ± 0	0.001 ±0.001
Pb (mg/l)	0.022 ±0.007	0.030 ±0.022	0.040 ±0.018	0.026 ±0.015
Ni (mg/l)	0.072 ±0.0126	0.110 ±0.171	0.041 ±0.014	0.086 ±0.138

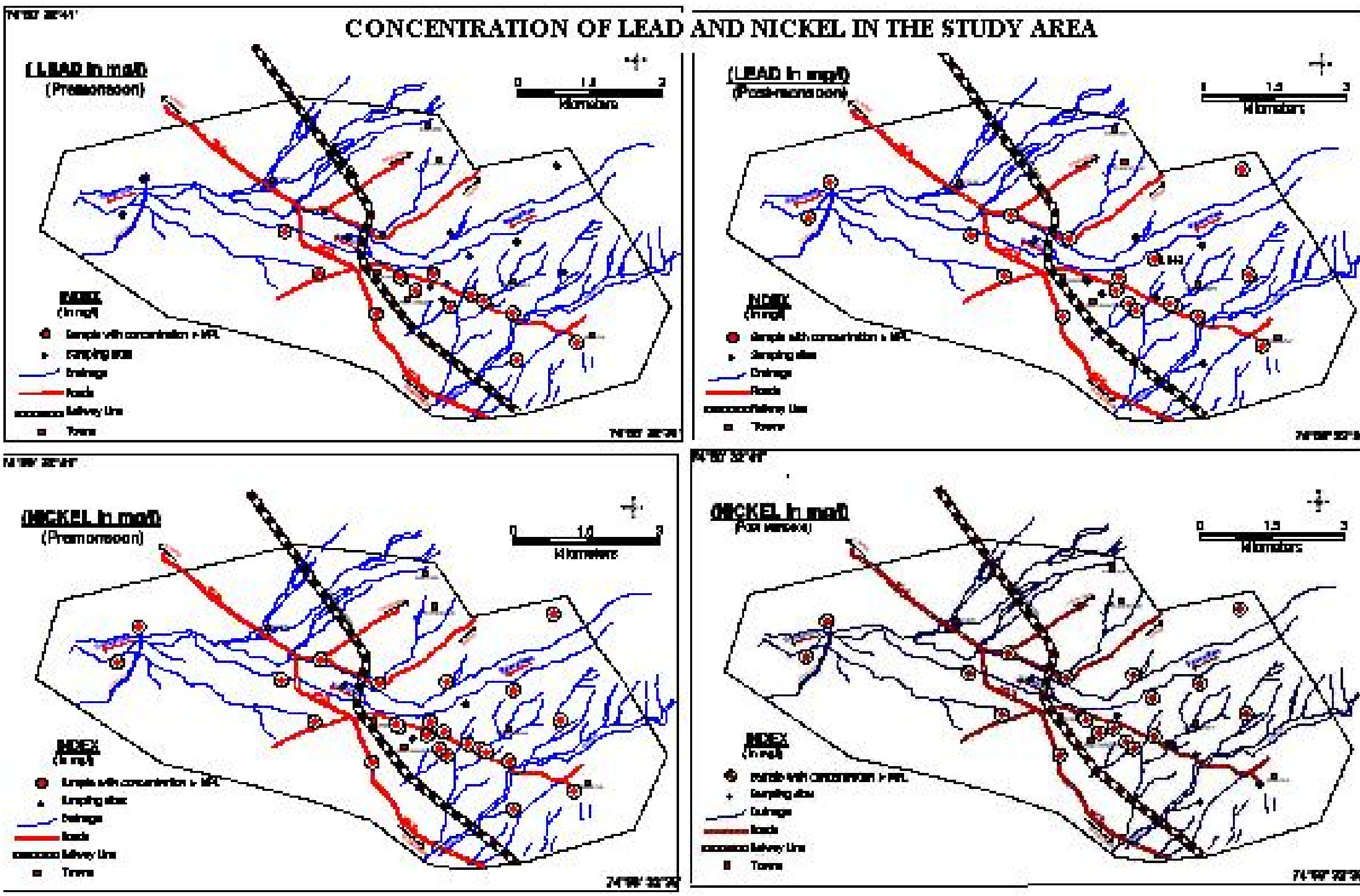

FIGURE 5: Point Values of Lead and Nickel in the Study Area

CONCLUSION

The hydro geological and hydrochemical studies carried out in and around the study area reveals the effect of pollutants on the ground water of the study area. Along with the waste disposed from the industries the nature of the aquifer also influences the scale of the contamination problem. Thus, in a highly porous aquifer where groundwater flow is easy and relatively rapid, contamination may become more widely dispersed in a given time than where flow is intergranular, especially if the strata have only a modest permeability. The Kandi formation behaves likewise and thus the contamination of ground water has not only remained in the surroundings of the study area but has moved laterally as well as affected the deeper aquifers. The preferential order of major cations and anions was determined and found that for shallow and deeper aquifers there is no change in the order of cations but for anions the concentration of NO_3 is more than SO_4 in shallow aquifers which indicates the anthropogenic pollution of shallow ground water in the area.The samples were collected from the shallow and deep ground water structures, that are used by the local residents for drinking and domestic uses, twice a year. These samples were found contaminated as most of them contained not only some of the physical contaminants but also they were found to have Pb, Ni, Cd, Fe, Mn etc. heavy metals. The analytical results of the samples collected from the study area revealed that further purification of waste water is required by the industries before its discharge, and ensure its suitability for human consumption. The study highlights the dire need to control the heavy metal contamination of groundwater, because if this is not stopped it will pose problems to provide safe drinking water in and around the study area.

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