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Spatial Variation Study of Heavy Metal in Ground Water of Southern Part of Upper Berach River

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A B S T R A C T

The present study was conducted to study heavy metal pollution in ground water of southern part of Upper Berach river. The water samples for the heavy metal analysis were collected from the open well of the 38 locations from Upper Berach river to find out concentration of different heavy metal such as Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn), Cadmium (Cd), Lead (Pb) and Nickel (Ni). The different heavy metals thematic maps of study area were prepared under GIS environment and the spatio-temporal variations of these parameters were analyzed. Results of the study indicates that about 57.94 per cent area shows Fe within BIS acceptable limit (< 0.3 mg/lit) and 42.06 per cent area show exceed Fe above acceptable limit of drinking purpose. About 42.03 per cent area shows Mn within BIS acceptable limit (< 0.1 mg/lit) and 57.97 per cent area shows Mn above permissible limit of drinking purpose.

Keywords

Heavy metal, Upper Berach River, GIS, spatio-temporal

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Introduction

Water, no doubt, is a boon of nature for the whole living world and is essential for variety of purposes to human beings as well as to plants and animals. Its many uses include drinking and other domestic uses, irrigation, power generation, transportation, industrial cooling, fishing, mining and fire fighting etc. Groundwater is one of the most valuable natural resources, which supports human health, socio-economic development, and functioning of ecosystems (Humphreys, 2009); Steube *et al.,* 2009). Heavy metal pollution is the contamination of water bodies such as lakes, rivers, oceans, and groundwater (Matta *et al.,* 2015). It occurs when pollutants are discharged directly or indirectly into water bodies without adequate treatment to remove harmful constituents. Water pollution is a major problem in the global context (Radha *et al.,* 2007). Sometimes pollutants like plant nutrients, bacteria, viruses, pesticides, herbicides, hydrocarbons, heavy metals and other toxic chemicals can enter through the groundwater thereby polluting it. Shallow groundwater is often affected by the land use. The quality of groundwater has been affected through domestic, agricultural and industrial pollution. Nitrates are predominant in western of Delhi (Adhikary *et al.,* 2010). Accumulation of heavy metals in crop plants is of great concern due to the probability of food contamination through the soil root interface. Though the heavy metal like, Cd, Pb and Ni are not essential for plant growth, they are readily taken up and accumulated by plants in toxic forms

Groundwater in deeper aquifers beneath the layers of rock or clay that do not let water through has better protection from pollution because it is not directly connected to the surface environment. Contaminants that may be present in source water include: Microbial contaminants such as viruses and bacteria, from sewage treatment plants, septic systems, agricultural livestock operations and wildlife. Ingestion of vegetables irrigated with waste water and grown in soils contaminated with heavy metals possesses a possible risk to human health and wildlife. Heavy metal concentration in the water plays an important role in controlling metal bioavailability to plants. Most of the studies show that the use of waste water contaminated with heavy metals for irrigation over long period of time increases the heavy metal contents of soils above the permissible limit. Inorganic contaminants, such as salts and metals can be naturally occurring or come from urban storm-water runoff (streets and parking lots), industrial or domestic wastewater discharges, oil and gas production, mining or farming. The use of remote sensing and GIS techniques is a fast emerging field in groundwater resource identification, mapping and planning. Remote sensing provides an opportunity for better observation and more systematic analysis of various geomorphic units, landforms, lineaments and drainages, due to its synoptic and multispectral coverage of a terrain (Ndatuwonga and Yadav, 2014). The aim of the study is to check the suitability of heavy metal in ground water for drinking purpose and to determine the potential of heavy metal pollution in southern part of Upper Berach River Basin, Rajasthan State using GIS technique.

Materials and Methods

Upper Berach River originates from Aravalli hills of South Rajasthan. It is a tributary of Banas river basin and situated in the Udaipur and Rajsamand district which is a part of semi-arid region of Rajasthan. The study area, 33.27 km^2 (Southern part of Upper Berach river basin) adjoining to zinc smelter, Debari is located between $73^0$48'30.28" to $73^0$52'53.5"E Longitude and $24^0$33'39.07" to $24^0$37'28.6"N Latitude and at about 580 m above mean sea level. The study area covers Bichadi, Sinhara, Ordi, Dabok, Gadwa, Rediya, Anandpura, Wakimagri, Changeri, Dhholikera, Chota gurha, Sakroda, Relamoti khera, Nora, Tala magri and Bgalon ka gurha villages. Groundwater samples were collected in sterilized sampling bottles and polythene bags. The study area is divided into 56 square grids (1km x 1km) and water samples were collected from 38 representative sites (open wells) is shown in fig.1. Global Positioning System (GPS) was used to record the position of sampling site. These samples were analyzed in the laboratory with help of Atomic

Absorption Spectrophotometer (AAS) to find out concentration of different heavy metal such as Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn), Cadmium (Cd), Lead (Pb) and Nickel (Ni). As per results obtained, the different heavy metals thematic map of study area were prepared under GIS environment to show spatial variation of heavy metals. The maps were generated by Inverse Distance Weighted Moving Average (IDWMA**)** in spatial analysis tool of GIS The procedures for thematic map generation are shown in Fig. 2.

Results and Discussion

Heavy metal study for drinking purpose

Water samples were collected from 38 sites in a sterilized plastic bottle. The site was open well with varies depth from 6.00 m to 33 m. Water samples were analyzed in the laboratory with help of Atomic Absorption Spectrophotometer (AAS).

The data value, maximum, minimum, mean value of the heavy metals and their Indian standard value are shown in Table 1. Spatial distributions thematic map of selected heavy metals are exhibited in Fig. 3 a-c.

Available Zinc

Zinc plays an important role in the metabolic activities of many organisms. In some respect, higher concentrations of zinc can be toxic to the organism. It is an essential mineral for human growth.

It plays an important role in protein synthesis and is a metal which shows fairly low concentration in surface water due to its restricted mobility from the place of rock weathering or from the natural sources. Zinc concentration in water ranged from 0.0334 to 1.1735 mg/lit with mean 0.133 mg/lit. All water samples were found within BIS acceptable limit (< 5 mg/lit) of drinking purpose. Minimum and maximum value was found in Chota Gurha-4 and Dabok-1.

Available Iron (Fe)

Iron in drinking water is present as Fe^{2+} or Fe^{3+} in suspended form. It causes staining in clothes and imparts a bitter taste. The main sources of Iron is natural geological sources, industrial wastes, domestic discharge and also from by products.

Mostly Iron is found in hemoglobin and myoglobin of a human body. Excess amount of iron causes rapid increase in pulse rate and coagulation of blood in blood vessels, hypertension and drowsiness. Iron concentration in water ranged from 0.06 to 1.275 mg/lit with mean 0.315 mg/lit.

Minimum and maximum value was found in Gadwa and Wakimagri. Fig. 3.a reveals that 57.94 per cent area show within BIS acceptable limit (< 0.3 mg/lit) and 42.06 per cent area show exceed Fe above permissible limit of drinking purpose.

Available Copper (Cu)

Contamination of drinking water with high level of copper may lead to chronic anemia. Copper accumulates in liver and brain. Copper particulates are released into the atmosphere by windblown dust, volcanic eruptions, anthropogenic sources such as primarily copper smelters and ore processing facilities. Copper concentration in water ranged from 0.005 to 0.081 mg/lit with mean 0.02 mg/lit. Minimum and maximum value was found in Sakroda-1 and Dholikhera.

All water samples were found within BIS acceptable limit (<.05) except Dholikhera village of drinking purpose.

Available Manganese (Mn)

Manganese concentration in water ranged from 0.014 to 0.532 mg/lit with mean 0.124 mg/lit. Minimum and maximum value was found in Sakroda-3 and Chota Gurha-1. Fig 3.b reveals that 42.03 per cent area show within BIS acceptable limit (< 0.1 mg/lit) and 57.97 per cent area show exceed Mn above acceptable limit of drinking purpose.

These results close conformity with the findings of Gupta *et al.,* (2011) and Tiwari *et al.,* (2016) who have reported that Mn concentration was found in groundwater sample above BIS permissible limits in industrial effluent area.

Available Lead (Pb)

Although lead occurs naturally in the environment, anthropogenic activities such as fossil fuels burning, mining, and manufacturing contribute to the release of high concentrations. Lead has many different industrial, agricultural and domestic applications.

It is currently used in the production of lead-acid batteries, ammunitions, metal products (solder and pipes), and devices to shield X-rays. Lead concentration in water ranged from 0.026 to 0.175 mg/lit with mean value of 0.079 mg/lit. Minimum and maximum value was found in Sakroda-1 and Dabok-1 respectively. All sample of study area show Lead concentration above BIS acceptable limit (0.01 mg/l) of drinking purpose.

Available Cadmium (Cd)

Cadmium is frequently used in various industrial activities. The major industrial applications of cadmium include the production of alloys, pigments, and batteries. It is a known human carcinogen. Although Cd is present in the environment naturally at a lower concentration, anthropogenic activities have elevated its level significantly over time. Major sources of Cd exposure are Ni/Cd batteries, Zn and Pb refineries, pigments and stabilizers for polyvinyl chloride, alloys, electronic products, fertilizers, pesticides, and disposal of industrial wastes. Cadmium toxicity impacts the kidneys leading to kidney dysfunction. It also impacts skeletal and respiratory systems and affects several enzymes. Cadmium concentration in water ranged from 0.002 to 0.037 mg/lit with mean value of 0.133 mg/lit. Cd concentration in all water samples were found above BIS acceptable limit (< 0.003 mg/lit) except Sinhara-2, Sakroda-1 and Bichadi-2 of drinking purpose. Minimum and maximum value was found in Sakroda-1 and Dabok-1 respectively. Dabok-1 is the lightly affected area where Cd was found maximum in water. These results close conformity with the findings of Yadav *et al.,* (2016) who has reported that concentration Cd in ground water sample was found above BIS permissible limits in industrial effluent area of Ahar river basin.

Available Nickel (Ni)

Nickel has been considered to be an essential trace element for human and animal health. Nickel concentration in water ranged from 0.005 to 0.069 mg/lit with mean 0.027 mg/lit.

Minimum and maximum value was found in Gadwa and Dabok-1. Fig. 3.c reveals that 17.58 per cent area show within BIS permissible limit (< 0.02 mg/lit) and 82.42 per cent area show exceed Ni above permissible limit of drinking purpose. These results close conformity with the findings of Yadav *et al.,* (2016) who has reported that concentration Mn in ground water sample was found above BIS permissible limits in industrial effluent area of Ahar river basin.

Table.1 Heavy Metal data of groundwater sample of southern part of Upper Berach river basin

Sr. No.	Village Name	Latitude	Longitude	Grid No.	Well Depth (M)	Water						
						Cu	Ni	Zn	Mn	Cd	Fe	Pb
1	Dabok Chowk	73°51'52.3"E	24°37'10.6"N	8	26.00	0.018	0.041	0.0503	0.035	0.013	0.183	0.094
2	Dabok Airport	73°52'35.2"E	24°37'22.4"N	9	25.10	0.028	0.05	0.0595	0.083	0.015	0.411	0.11
3	Gadwa	73°50'19.8"E	24°36'23.1"N	14	21.20	0.014	0.005	0.0637	0.043	0.007	0.06	0.044
4	Rediya (Gadwa)	73°51' 03.9"E	24°36'26.8"N	15-1	22.80	0.017	0.044	0.1621	0.084	0.018	0.178	0.13
5	Anand Pura	73°50'47.9"E	24°36'28.4"N	15-2	20.00	0.015	0.029	0.0653	0.143	0.011	0.127	0.089
6	Wakimagri	73°51'41.6"E	24°36'24.3"N	16	29.50	0.027	0.054	0.1974	0.112	0.018	1.275	0.148
9	Dabok-1	73°52'13.0"E	24°36'31.8"N	17-1	19.00	0.026	0.069	1.1735	0.066	0.037	0.19	0.175
8	Dabok-2	73°51'56.9"E	24°36'48.3"N	17-2	23.00	0.012	0.025	0.1732	0.131	0.012	0.267	0.111
15	Dabok-3	73°51'48.9"E	24°36'49.5"N	17-3	26.80	0.008	0.023	0.0705	0.035	0.006	0.348	0.068
7	Bichadi-1	73°49'54.5"E	24°35'58.6"N	22	8.00	0.011	0.027	0.0799	0.362	0.012	0.18	0.066
10	Bichadi-6	73°50'24.2"E	24°35'55.5"N	23	15.1	0.039	0.045	0.3861	0.047	0.02	0.303	0.146
11	Sinhara-1	73° 51'01.0E	24°35'52.3"N	24-1	13.00	0.013	0.02	0.0742	0.127	0.01	0.246	0.047
12	Sinhara-3	73 50 53.1 E	24 35 41.4N	24-2	19.00	0.018	0.035	0.0933	0.03	0.011	0.103	0.063
13	Ordi-2	73°52'13.6"E	24°36' 04.9"N	26-1	6.0	0.01	0.014	0.1264	0.074	0.011	0.298	0.074
14	Changeri-2	73°51'45.5"E	24°35'50.9"N	26-2	18.80	0.01	0.028	0.0634	0.094	0.006	1.23	0.064
16	Bichadi-2	73°49'43.1"E	24°35'31.8"N	30-1	21.80	0.011	0.02	0.1189	0.378	0.003	0.184	0.062
17	Bichadi-4	73°49'45.0"E	24°35'34.3"N	30-2	6.70	0.013	0.016	0.1033	0.091	0.011	0.163	0.062
18	Bichadi-7	73°50' 05.5"E	24°35'32.4"N	30-3	13.00	0.013	0.021	0.0761	0.027	0.008	0.111	0.065
19	Sinhara-2	73°51' 25.9"E	24°35' 46.5"N	33	21.80	0.012	0.016	0.0826	0.085	0.003	0.343	0.057
20	Changeri-1	73 51 45.5 E	24 35 46.4N	34-1	11.00	0.009	0.019	0.0805	0.21	0.004	0.19	0.074
21	Dholikhera	73°51' 44.4"E	24°35' 30.2"N	34-2	15.30	0.081	0.026	0.1641	0.076	0.012	1.165	0.088
22	Ordi-1	73°52'18.7"E	24°35'47.4"N	35-1	26.60	0.018	0.029	0.1382	0.124	0.013	0.365	0.091
23	Ordi-3	73°52'24.1"E	24°35'20.0"N	35-2	27.50	0.012	0.022	0.0349	0.047	0.008	0.213	0.053
24	Bichadi-5	73°49'50.966"E	24°35'5.946"N	38	12.60	0.006	0.009	0.1516	0.06	0.01	0.084	0.043
25	Chota Gurha-1	73 50 24.9	24 34 45.2	39-1	17.60	0.043	0.034	0.1206	0.532	0.009	0.227	0.072
26	Chota Gurha-3	73 50 18.7 E	24 35 06.8N	39-2	8.4	0.036	0.028	0.0593	0.125	0.013	0.161	0.081

27	Chota Gurha-4	73° 50 28.1 E	24 35 10.1N	39-3	33.00	0.012	0.017	0.1067	0.092	0.014	0.138	0.05
28	Chota Gurha-5	73 50 26.7E	24 34 52.5N	39-4	25.40	0.027	0.051	0.0549	0.076	0.02	0.14	0.136
29	Chota Gurha-6	73 50 15.1E	24 34 58.0N	39-5	15.30	0.011	0.02	0.0334	0.069	0.007	0.089	0.059
30	Bichadi-3	73°50'12.4"E	24°35'09.6"N	39-6	18.10	0.032	0.028	0.1179	0.151	0.012	0.305	0.154
31	Sakroda-1	73°51' 02.2"E	24°35' 01.2"N	40-1	13.00	0.005	0.009	0.0378	0.454	0.002	0.446	0.026
32	Sakroda-3	73°51' 06.7"E	24°34'46.0"N	40-2	23.50	0.013	0.025	0.0433	0.014	0.008	0.131	0.048
33	Rella moti khera	73°52'19.5"E	24°34'53.3"N	43	24.90	0.027	0.006	0.1523	0.068	0.01	0.543	0.042
34	Chota Gurha-2	73 50' 26.9" E	24°34 34.7 N	45	17.90	0.043	0.021	0.1067	0.221	0.014	0.344	0.066
35	Bhalon ka Gurha	73°50' 39.9"E	24°34'22.1"N	46	26.10	0.025	0.032	0.0606	0.04	0.014	0.274	0.068
36	Nora	73°51'40.0"E	24°34'20.0"N	47-1	22.60	0.008	0.022	0.1116	0.067	0.01	0.128	0.047
37	Sakroda-2	73°51'22.6"E	24°34'19.1"N	47-2	25.00	0.018	0.019	0.1785	0.196	0.007	0.646	0.067
38	Tala magri	73°52'10.9"E	24°34'32.4"N	48	22.40	0.025	0.016	0.0752	0.046	0.01	0.172	0.069
Max						0.081	0.069	1.174	0.532	0.037	1.275	0.175
Min.						0.005	0.005	0.033	0.014	0.002	0.060	0.026
Mean						0.020	0.027	0.133	0.124	0.011	0.315	0.079

Table.2 Correlation matrix for different heavy metal parameters in water sample

Parameter	Cu	Ni	Zn	Mn	Cd	Fe	Pb
Cu	1	0.318	0.184	0.038	0.355	0.399	0.380
Ni	0.318	1	0.543	-0.114	0.788	0.150	0.834
Zn	0.184	0.543	1	-0.083	0.767	0.028	0.570
Mn	0.038	-0.114	-0.083	1	-0.271	0.030	-0.147
Cd	0.355	0.788	0.767	-0.271	1	-0.011	0.767
Fe	0.399	0.150	0.028	0.030	-0.011	1	0.169
Pb	0.380	0.834	0.570	-0.147	0.767	0.169	1

Fig.1 Grid map and location map of heavy metal sample sites

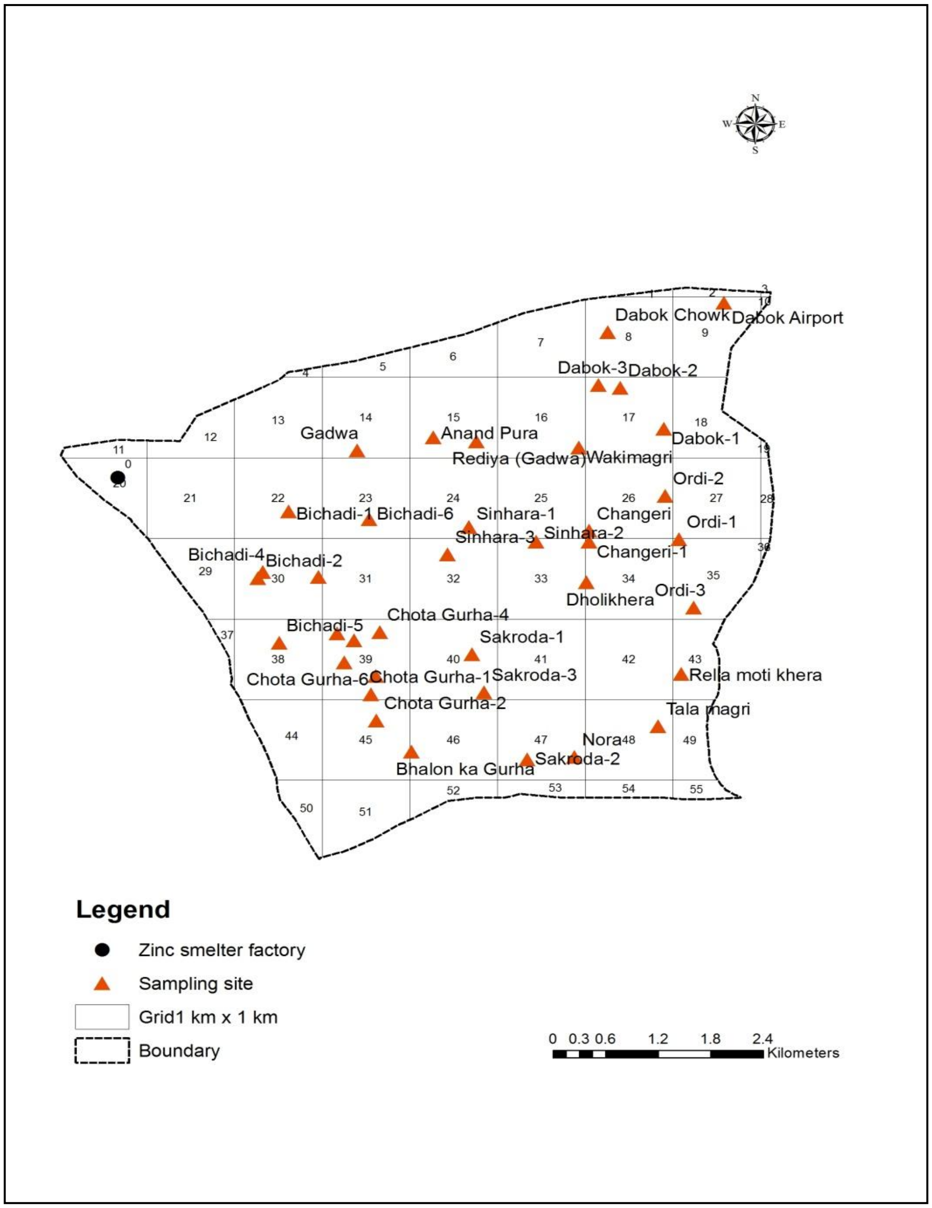


Fig.2 Flow chart for generation of spatial distribution map

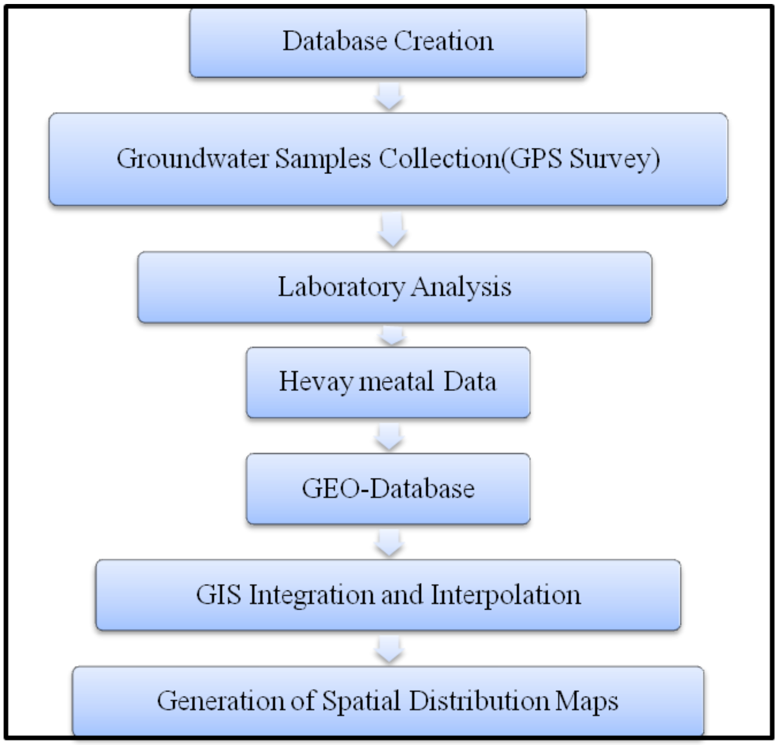


Fig.3a Variation of Fe in ground water sample

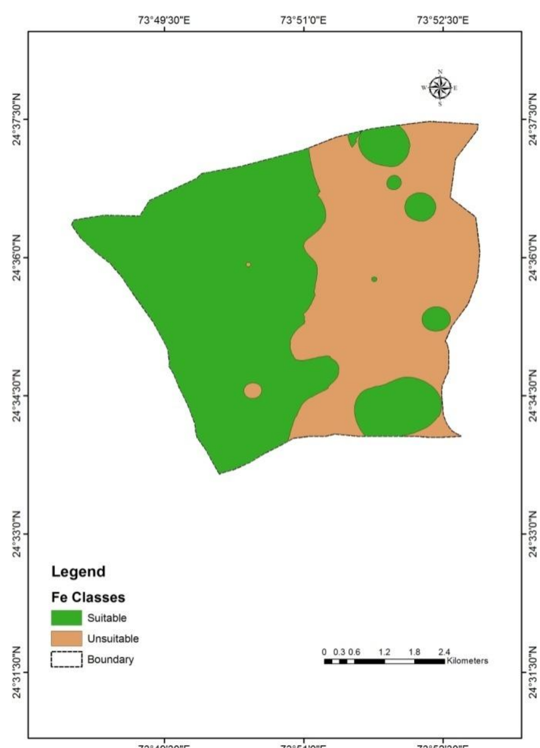


Fig.3b Variation of Mn in ground water sample

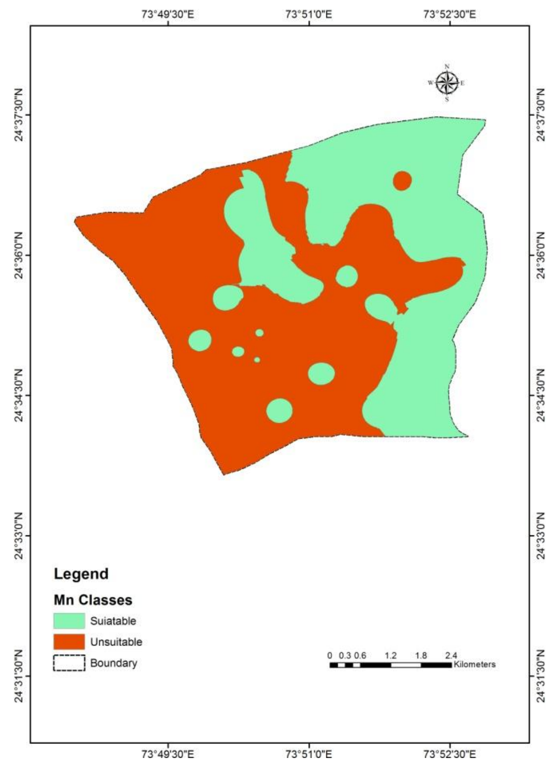
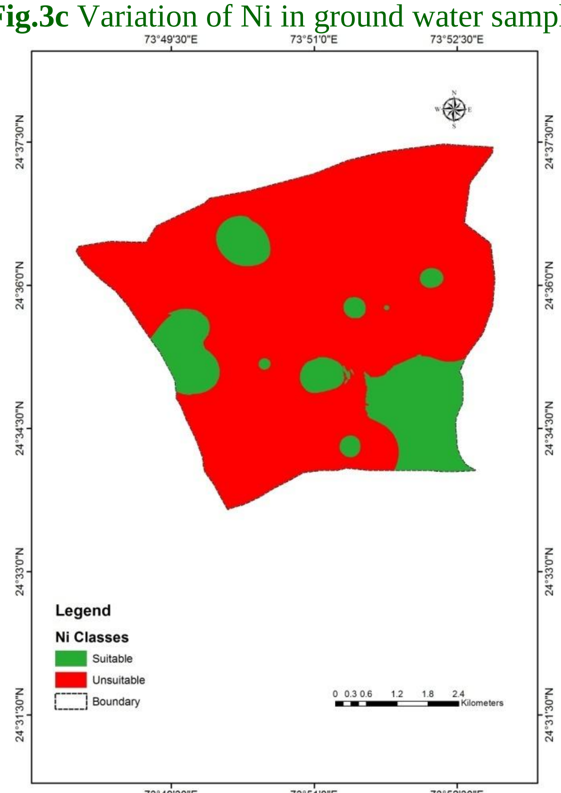


Fig.3c Variation of Ni in ground water sample



Correlation Study

Heavy metals in water usually have complicated relationships among them and numerous factors control their relative abundance e.g., original contents of heavy metals in parent materials, rocks and various processes of soil formation and anthropogenic factors such as contamination by mining activity and human activity. The correlation coefficients (r) analysis was performed among seven heavy metals in water and soil namely Cu, Ni, Zn, Mn, Cd, Fe and Pb and given in Table 2. The highly significant and strong positive correlation identified between Ni-Zn, Cd, Pb; Zn-Cd, Pb in water samples. Such correlation between heavy metals in water may reflect that these heavy metals had similar pollution level and sources. Copper shows weak and positive correlation with all heavy metals in water samples. Ni and Zn shows weak and positive correlation with Fe and negative correlation with Mn in water samples. Iron shows weak and positive correlation with all parameters except Cd in water samples. Overall the elements Cu, Ni, Zn, Mn, Cd, Fe and Pb are grouped together, indicating that the anthropogenic sources of these heavy metals are closely related in the water and soil of study area.

Specific conclusions drawn based on the results of the study are listed below.

About 57.94 per cent area shows Fe within BIS acceptable limit (< 0.3 mg/lit) and 42.06 per cent area show exceed Fe above acceptable limit of drinking purpose.

About 42.03 per cent area shows Mn within BIS acceptable limit (< 0.1 mg/lit) and 57.97 per cent area shows Mn above permissible limit of drinking purpose. About 17.58 per cent area show within BIS permissible limit (< 0.02 mg/lit) and 82.42 per cent area show exceed Ni above permissible limit of drinking purpose.

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