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Assessment of Groundwater Contamination Due To Heavy Metal Accumulation: A Study from Tadipatri Area, Andhra Pradesh

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Abstract

Groundwater collected around cement and steel industrial areas of Tadipatri area, Andhra Pradesh have been analyzed for their physicochemical parameters and heavy metal content to assess the water quality with reference to drinking. The analytical data of these water samples reveal pH values of all samples are within desirable limit showing alkaline nature. To ascertain the suitability of groundwater for drinking and public health purposes, these hydrochemical parameters of the study area are compared with the guidelines recommended by BIS (1991).It is evident that the groundwater of the study area has concentrations of some heavy metals viz., Fe, Cr and Ni present above the permissible levels recommended for drinking water by the BIS. Cu, Mn and Pb in few samples are found above the desirable limits; however the concentrations of Zn and Al are below the desirable limits of BIS. Industrial waste, anthropogenic activities and municipal sewage could be the main cause of groundwater contamination. Presence of higher concentration of heavy metals would expose the population to health hazards. The results of the study area reveal that, metal concentrations in some of the groundwater samples are highly contaminated and therefore partially not suitable for drinking purposes. Hence the groundwater to be continuously evaluated and need for regular groundwater quality monitoring to assess pollution activity.

Keywords: *groundwater quality, heavy metals, contamination, Tadipatri, Andhra Pradesh*

Introduction

Water is one of the most essential requirements of mankind to sustain domestic, drinking, agricultural, industry and other needs. Therefore, water quality is one of the most important aspects in groundwater studies. The quality of groundwater is influenced by natural and anthropogenic factors and any deterioration in water quality could affect human health. Groundwater quality problems have emerged in many geographical areas due to natural environmental processes and human intervention in the geosystems. Pollution of groundwater due to industrial effluents and municipal waste in water bodies is major concern in many parts of India. It leads to deterioration of groundwater quality. Heavy metals occur in the earth's geological structures, and can therefore enter water resources through natural processes. Heavy rains, flow of water can leach heavy metals out of geological formations. Many industrial processes can generate heavy metal pollution, in a number of ways. Heavy metals in subsurface environments come from natural and anthropogenic sources. The weathering of minerals is one of the major natural sources. Anthropogenic sources include fertilizers, industrial effluent and leakage from service pipes. A great deal of concerns has been expressed over problems of groundwater contamination by heavy metals due to rapid industrialization, urbanization and various

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other activities in many parts of India. Heavy metals are produced from a variety of natural and anthropogenic sources such as geological weathering, residential, industrial products agricultural activities, and corrosion products of soil (Grolimund *et al.*, 1996 Demirak *et al.*, 2006). These heavy metals have the potential to reach levels in the soil and then in the surface and groundwater that are adverse to human health (Rashed, 2010; Chotpantarat and Sutthirat, 2011; Taboada-Castro *et al.*, 2012).some of the elements are useful to organisms for the maintenance of health but its deficit in diet inhibits growth and vitality of humans, animals and plants to a certain level (Edet *et al.*, 2003). Heavy metals present in trace concentration play a major role in the metabolism and health growth of plants and animals. The same metals, however, in higher concentrations may have severe toxicological effects on human being (Chapman, 1992).

Heavy metals such as lead and mercury are toxic metals and their accumulation over time in the bodies of animals can cause serious illness, and some of the elements like cobalt, copper, chromium, manganese, nickel are actually necessary for humans in minute amounts at the same time the deficiency of trace elements is equally harmful. But the trace metals can be toxic and even harmful to humans even in relatively low concentrations because of their tendency to accumulate in the body (Domenico and Schwartz, 1998). The main sources of heavy metals in natural waters are natural and anthropogenic activities. The intensive anthropogenic stress on the land water resources of country has disturbed the quality of the soil and water. These elements can accumulate in plants and animals eventually enter humans through food chain (Singh *et al.*, 2006). Heavy metal pollution can arise from many sources but most commonly arises from the purification of metals. Contamination of groundwater by heavy metals can pose a more serious and continuing health risk to humans and environment (Tripathi and Pandey, 2001). Several earlier workers (Schwartz, 1997; Ghose, 2003; and Romic and Romic, 2003; Abhay Kumar Singh *et al.*, 2011; Jeemuta Vahana et al. 2011; Deshpande *et al.*, 2013 and Fakhre Alam and Rashid Umar, 2013) have worked on heavy metal and trace elements contamination in groundwaters and surface waters and its adverse effects on human body.

Study area

The study area Tadipatri is located at 14^{o}92'N 78^{o}02'E, Anantapur District, Andhra Pradesh (Fig.1). Geologically the area is mostly occupied by dolomites, limestones and shales. The climate of the area is characterized by hot summers and mild winters. Maximum temperature is 40^{o}C during summer and during winter minimum temperature is 22^{o}C. In this area groundwater occurs under semi-confined conditions. The fractures constitute the porosity and permeability of the rocks. The area receives rain fall from monsoon period. Groundwater has been used for various purposes, such as drinking, agricultural and domestic needs. Cultivation is common in this area. Agricultural activity included sunflower, groundnuts, jowar, cotton and vegetables. The study area Tadipatri is surrounded by cement, steel and thermal power

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industries, and also napa slabs and cement grade limestone mining activities, that have inevitable impacts on the environment resulting in various environmental problems and causes the main source of water pollution. Groundwater depletion and quality deterioration is the major concern in the area. The waste products released from the anthropogenic activities and other industries constitute the main cause for the degradation of water quality in the area. Hence, the present investigations were carried out in and around Tadipatri area to determine the various quality parameters of groundwater and the concentrations of heavy metals like Fe, Cu, Pb, Zn, Mn, Al, Cr and Ni distribution in the groundwater and its quality in and around Tadipatri area This study also helps to suggest adequate strategies and mitigative measures to be implemented to avoid further deterioration of the environment for sustainable development.

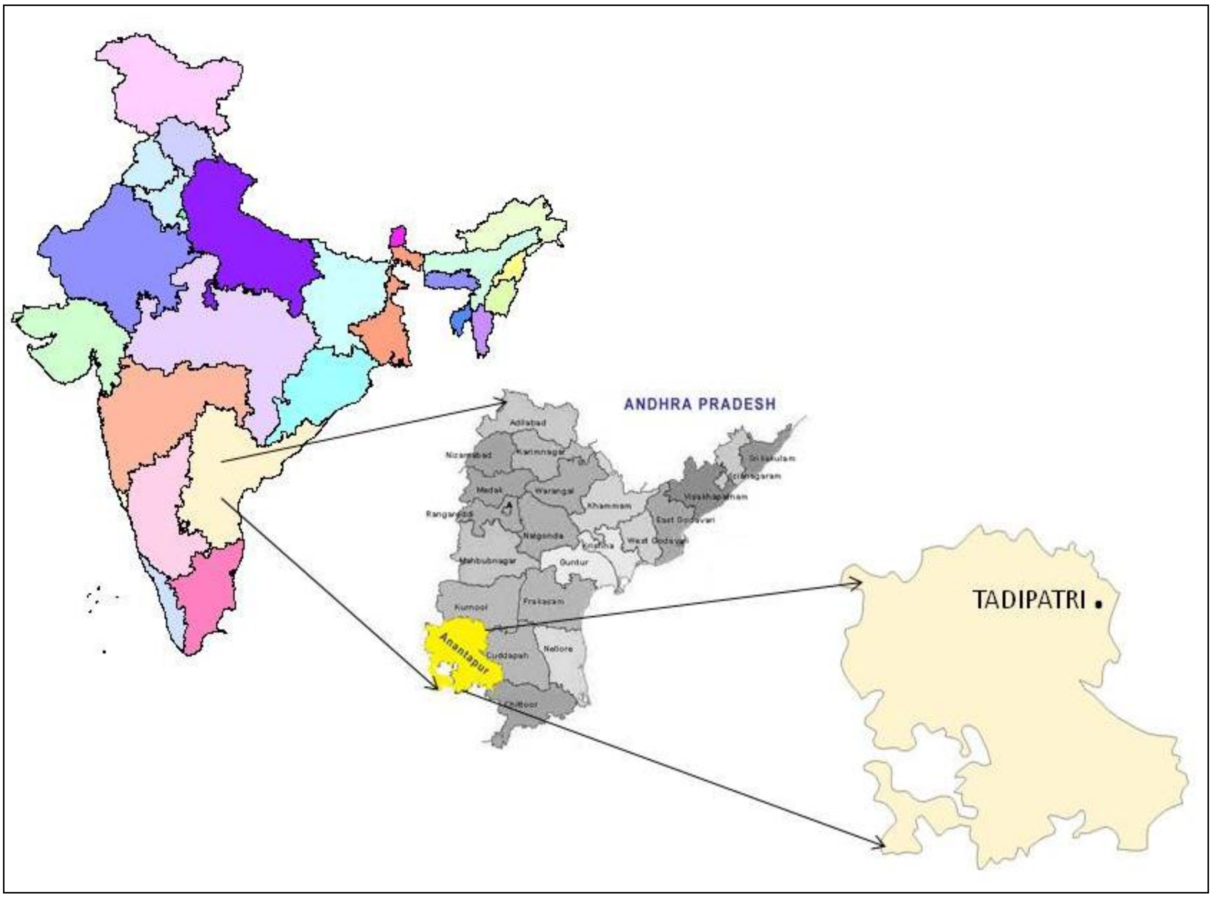

Fig.1. Location map of the study area

Methodology

The objective of the present investigation is to assess various quality parameters of groundwater and their heavy metal content .To assess the groundwater quality, 26 samples of groundwater were collected from bore-wells and hand pump wells in pre-washed1L polyethylene bottles around cement and steel industrial areas of Tadipatri, Andhra Pradesh in the month of October-November 2011. Prior to the collection of the samples, the hand pumps were duly pumped so that the stagnant water, if any, is completely removed from storage in the well assembly. These samples were acidified by HNO_3. For collection, preservation and analysis of the samples, the standard methods were followed (APHA, 1992, 1995). Water samples have been analyzed for their physicochemical parameters **(**EC, pH, TDS, Ca, Mg, Na, K, Cl, SO_4, HCO_3, NO_3 and CO_3) and heavy metals **(**Fe, Cu, Pb, Zn, Mn, Al, Cr and Ni**)** content to assess the water quality with reference to drinking. Electrical conductivity **(**EC), pH, and total dissolved solids (TDS) were measured in the field by their respective meters. The chemical parameters like Cl, Ca, Mg, HCO_3 and CO_3 were determined by standard titrimetric methods. Na and K were analyzed by flame photometer, SO_4 and NO_3 is determined by spectrophotometer. Heavy metals like Fe, Cu, Pb, Zn, Mn, Al, Cr and Ni were analyzed by Atomic Absorption Spectrophotometer (AAS). The analytical results obtained are compared with the standard values recommended by BIS (1991) specifications for drinking purpose.

Results and Discussions

Hydrogeochemistry of groundwater

The groundwater samples of the study area were analyzed for their physicochemical parameters and heavy metal content presented in Table 1 and 2 respectively. Table 1 shows the physicochemical parameters of groundwater. Table 2 shows the concentration of heavy metals in the groundwater samples collected in the study area. The analytical results show that pH of groundwater varies from 604 to 8.2; pH values are within the desirable limit of 6.5 to 8.5 as recommended by BIS (1991). The electrical conductivity (EC) of groundwater varies between 341 to 1250 μS/cm. The estimated total dissolved solids (TDS) is in the range of 210 to791 mg/l, whereas the acceptable limit is 500 mg/l BIS (1991). 58% of the groundwater is exceeds the permissible limit. High concentrations of sodium, calcium and magnesium and anthropogenic activities are responsible for high amounts of TDS. According to the classification of TDS (Fettar, 1990), 100% groundwater samples come under fresh (TDS <1000 mg/l) category. Among the cationic (Ca, Mg, Na, and K) concentrations, Na is the dominant (17 to 292 mg/l), followed by Ca (13 to 160 mg/l) Mg (12 to 40 mg/l), and K (5 to 30 mg/l). The SO_4 is the predominant ion (14 to 410 mg/l) among the anionic (HCO_3, Cl, SO_4, NO3, and CO_3) concentrations and is followed by the Cl (19 to 286 mg/l), HCO_3 (41 to 276 mg/l), NO_3 (5 to 106 mg/l) and SO_4 (14 to 410 mg/l).

Heavy metal Concentration in Groundwater

Chromium (Cr)

Chromium is an essential trace element required for the metabolism of lipids and protein and to maintain a normal glucose tolerance factor. High doses of chromium cause liver and kidney damage and chromate dust is carcinogenic (SEGH, 2001; Mugica *et al.*, 2002).The maximum permissible limit of chromium (Cr) in drinking water is usually 0.05 mg/l (BIS, 1991). The concentration of Cr in the groundwater of the study area ranges from 0.005to 0.069 mg/l with an average of 0.0353 mg/l. In 3 samples the concentration of Cr has exceeded the maximum permissible limit of as given by BIS (1991). In the study area High

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concentration of Cr values may be related to the sewage sludge (Deshpande *et al.*, 2013). Chromium may cause skin disorder and cancer in respiratory trace (Goel, 1997).11.53% of groundwater samples exceeded the permissible limit.

Lead (Pb)

Lead concentration in natural water increases mainly through anthropogenic activities (Goel, 1997). The possible sources of Pb in groundwater are mainly due to discarded batteries, paint, mining, milling smelting of lead combustion of fossils fuels and municipal wastes. Major sources of lead pollution include lead-acid storage batteries, electroplating, materials, ceramics, glassware, and gasoline. The concentration of lead in groundwater varies from 0.004 to 0.586 mg/l with an average concentration 0.0945 mg/l as against the desirable limit of 0.1 mg/l (BIS, 1991) the concentrations of Pb in 3 samples are above the desirable limit. The main sources of lead contamination in the study area may be industrial discharges, runoff from contaminated land areas and sewage effluents (Purushotham *et al.*, 2013). Lead can cause neurological and behavioral disorders, especially in children, anemia, impaired kidney and testicular function (Barzilay *et al.*, 1999).

Table 1. Hydrochemical Analysis of Groundwater Samples from Tadipatri Area

[The values are in mg/l except pH; and EC (µS/cm).

S.No	pH	EC	TDS	Na	K	Mg	Ca	CO_3	HCO_3	SO_4	NO_3	Cl
1	6.9	975	570	78	8	24	39	10	192	60	36	219
2	7.7	1060	590	220	10	20	49	6	184	28	16	165
3	7.5	721	595	120	11	14	64	8	99	118	75	37
4	7.2	341	260	170	14	25	25	5	176	186	30	40
5	7.9	900	520	124	5	22	70	12	74	260	20	72
6	7.3	1200	750	110	8	19	75	12	62	82	40	30
7	7.9	1230	728	39	16	20	40	7	196	410	98	200
8	6.8	690	329	49	6	12	65	9	48	94	22	175
9	7.9	789	415	292	28	40	114	25	200	352	38	256
10	7.2	990	680	92	12	21	60	9	134	105	45	109
11	7.5	453	252	39	12	31	36	12	79	143	49	214
12	7.9	810	510	210	12	26	74	4	180	171	29	20
13	6.9	700	440	114	7	27	58	16	173	59	35	23
14	6.7	890	520	94	6	34	66	10	175	65	18	35
15	7.4	915	514	28	8	26	88	9	86	19	35	56
16	6.9	694	450	84	30	25	74	35	179	69	5	270
17	7.8	860	536	280	6	18	25	7	50	98	36	79
18	7.3	792	440	40	5	16	81	8	70	57	31	240
19	7.4	691	455	26	9	13	160	6	276	45	42	89
20	8.1	426	292	20	20	17	60	6	60	14	62	35
21	6.7	1250	760	84	18	21	30	7	196	98	45	19
22	6.6	390	250	20	13	18	94	5	188	57	106	160
23	7.7	370	210	69	26	24	13	8	94	68	37	99
24	8.2	854	565	62	25	28	26	14	41	68	29	36
25	6.9	1200	791	17	20	21	70	20	196	54	29	47
26	6.4	790	540	86	9	27	60	6	89	47	35	210
Min	6.4	341	210	17	5	12	13	4	41	14	5	19
Max	8.2	1250	791	292	30	40	160	35	276	410	106	286
Avg	7.33	806	498	102	13	22	63	11	136	116	41	118

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Table 2 Heavy Metal concentration (mg/l) in groundwater of the study area.

S No	Al	Cr	Mn	Fe	Ni	Cu	Zn	Pb
1	0.026	0.025	0.025	0.060	0.095	0.027	0.098	0.047
2	0.014	0.038	0.092	0.120	0.110	0.083	0.065	0.012
3	0.018	0.045	0.054	1.00	0.084	0.016	0.024	0.049
4	0.021	0.023	0.095	0.054	0.064	0.096	0.075	0.073
5	0.020	0.025	0.095	0.426	0.386	0.050	0.068	0.586
6	0.03	0.065	0.152	1.195	0.025	0.024	0.025	0.1
7	0.019	0.041	0.084	1.098	0.243	0.044	0.056	0.115
8	0.026	0.050	0.064	0.642	0.321	0.042	0.086	0.004
9	0.028	0.035	0.100	0.452	0.150	0.035	0.072	0.081
10	0.022	0.054	0.047	0.450	0.154	0.038	0.019	0.085
11	0.014	0.041	0.068	0.158	0.372	0.035	0.016	0.007
12	0.025	0.036	0.092	0.196	0.058	0.012	0.068	0.120
13	0.024	0.030	0.075	0.264	0.046	0.033	0.058	0.008
14	0.016	0.005	0.198	0.541	0.092	0.039	0.100	0.035
15	0.019	0.048	0.091	0.951	0.037	0.042	0.071	0.064
16	0.025	0.050	0.084	0.458	0.256	0.025	0.024	0.050
17	0.023	0.044	0.097	0.059	0.215	0.015	0.069	0.183
18	0.027	0.025	0.045	1.203	0.063	0.047	0.018	0.051
19	0.017	0.069	0.034	0.542	0.042	0.046	0.013	0.056
20	0.014	0.047	0.065	1.083	0.096	0.032	0.047	0.048
21	0.015	0.037	0.018	1.000	0.213	0.026	0.039	0.054
22	0.013	0.015	0.016	0.694	0.190	0.039	0.084	0.019
23	0.026	0.013	0.021	0.915	0.300	0.031	0.044	0.082
24	0.016	0.018	0.048	1.065	0.040	0.016	0.067	0.006
25	0.022	0.020	0.075	0.440	0.078	0.048	0.044	0.046
26	0.028	0.017	0.085	0.395	0.115	0.045	0.089	0.075
Min	0.013	0.005	0.016	0.054	0.025	0.012	0.013	0.004
Max	0.03	0.069	0.198	1.203	0.386	0.096	0.1	0.586
Avg	0.0211	0.0353	0.0762	0.5970	0.152	0.0390	0.0554	0.0945

Table 3. Range of concentration of Heavy metals in groundwater samples and their comparison with BIS (1991) specifications for drinking water standards (All ions in mg/l; except pH; EC in μS/cm).

constituents	BIS (1991) (mg/l)		Ranges of Values in the study area (mg/l)	No. of samples of beyond the permissible limit	Percentage of samples of beyond the permissible limit
	Highest desirable level	Maximum permissible level			
Copper (Cu)	0.05	1.5	0.012-0.096	Nil	Nil
Iron(Fe)	0.3	1	0.054-1.203	5	19.23%
Nickel (Ni)	0.1	0.3	0.025-0.386	3	11.53%
Manganese (Mn)	0.1	0.5	0.016-0.198	Nil	Nil
Aluminum (Al)	0.03	0.2	0.013-0.03	Nil	Nil
Chromium(Cr)	0.05	0.05	0.005-0.069	3	11.53%
Zinc (Zn)	0.1	15	0.013-0.1	Nil	Nil
Lead (Pb)	0.1	-	0.004-0.586	Nil	Nil

Iron (Fe)

Iron is essential element in human nutrition. Toxic effects manifested with overdose of iron supplements. Anemia caused by lack of iron is the commonest nutritional deficiency in the World (Raju, 2006). Iron in the normal ground water is mostly in the form of inorganic complexes derived from laterites and other types of soils. In this study, the Fe concentration was found between 0.054 to 1.203 mg/l with an average concentration 0.5970 mg/l. In 5 samples the concentration of Fe has exceeded the maximum permissible limit of 1.0 mg/l as recommended by BIS (1991). 19.23% of samples the exceeded the BIS (1991) permissible limit in the study area. Excess of Fe would be mostly accumulated and discharged through the steel industrial effluents. Naturally occurring iron minerals are magnetite, hematite, goethite and siderite. Weathering processes along with corrosion products release iron in water (Smith, 1981).

Nickel (Ni)

Nickel is a dietary requirement for many organisms, but may be toxic in larger doses (Deshpande et al. 2013).The range of nickel concentration in groundwater varies from 0.025 to 0.386 mg/l, with an average concentration 0.152 mg/l. In 3 samples the concentration of Ni has exceeded the maximum permissible limit of 0.3 mg/l as given by BIS (1991). Sources of nickel include municipal sewage sludge, waste water plants, and groundwater near landfill sites (Purushotham *et al.*, 2013).The primary source of nickel in drinking water is leaching from metals in contact with drinking water, such as pipes and fittings (WHO, 2005). 11.53% of samples the exceeded the BIS (1991) permissible limit in the area of study.

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Copper (Cu)

Copper is an essential element for the formation of enzymes in human beings. Intake of excessively large doses of copper leads to severe mucosal irritation and corrosion, wide spread capillary damage, heptic and renal damage followed by depression. Copper toxicity includes blue green diarrhea stool and saliva (Athor and Vohora, 1995). Copper concentration varies from 0.012 to 0.096 mg/l, with an average concentration 0.0390 mg/l. Except two samples all the groundwater samples have values with in desirable limit of 0.05 mg/l as prescribed by BIS (1991). The high concentration of copper in the groundwater is mainly due to anthropogenic activities (Purushotham *et al.*, 2013). Toxicity of copper to aquatic life is dependent on the alkalinity of water as copper is generally more toxic to aquatic fauna at lower alkalinities (Train, 1979).

Zinc (Zn)

Zinc concentration in groundwater of the study area ranges from 0.013 to 0.1 mg/l with an average concentration of 0.0554 mg/l. The Bureau of Indian standards has prescribed 0.1 mg/l zinc as the desirable limit and 15 mg/l as the permissible limit for drinking water (BIS, 1991. It is observed that all the samples have values within desirable limit 0.1 mg/l as recommended by BIS (1991). The main sources of Zn pollution are industries and the use of liquid manure, composted materials, and agrochemicals such as fertilizers and pesticides in agriculture (Romic and Romic, 2003). Symptoms of zinc toxicity includes vomiting, lethargy, muscle inco-ordination and dehydration (Sandsted, 1975)

Manganese (Mn)

Manganese is one of the more abundant metals in the earth's crust and usually occurs together with Fe. Manganese (Mn) is similar to iron in its chemical behaviors and frequently found in association with Fe. Manganese concentration in the groundwater ranges from 0.016 to 0.198 mg/l, with an average of 0.0762 mg/l. Except for 2 samples all the values of manganese are within the desirable limit of 0.1 mg/l as recommended by BIS (1991). The presence of manganese above the permissible limit of drinking water often imparts an alien taste to water and also has adverse effects on domestic uses and water supply structures (Deshpande *et al.*, 2013).

Aluminum (Al)

The concentration of aluminum in groundwater ranges from 0.013 to 0.03 mg/l, with an average concentration of 0.0211 mg/l. The maximum permissible limit of aluminum is 0.2 mg/l (BIS, 1991). Aluminum values in the study area ranges from 0.371 to 3.712 mg/l, and the entire sample have within the desirable limit.

Conclusions

Groundwater depletion and quality deterioration are the main concerns in the study area caused due to industrialization and unscientific disposal of wastes and improper water management. The present study was carried out on the distribution of heavy metals and the major ion chemistry in groundwaters of Tadipatri area reveal that the concentration of cations is in the order Na>Ca>Mg>K while for anions it is $Cl>HCO_3>SO_4>NO_3>CO_3$. The pH values of all samples are within the desirable limits showing slightly alkaline nature. Based on the TDS about 42% of groundwater samples exceeded the desirable limits for the drinking water. The heavy metals like Fe, Cr, and Ni are found in high concentrations and exceeding the permissible limits of BIS. In few groundwater samples the concentrations of Cu, Mn and Pb, at some sites are found above the desirable limit of drinking water specified by Indian standard (BIS 1991). However the concentrations of Zn, and Al are found below the desirable limits for drinking water. Presence of higher concentration of heavy metals would expose the population to health hazards. Due to lack of the industrial management, mining, industrial effluents anthropogenic activities and municipal waste have probably contributed to the increase in the concentration of the heavy metals in groundwater. The materials from industries and anthropogenic activities and municipal sewage enters the surface water and migrates to subsurface aquifer either through joints, fractures and soil layers or through chemical weathering increasing the level of pollution in the groundwater. Municipal sewage and industrial effluents could be the main cause of the groundwater contamination. High level of these metals in groundwater can harm ecosystems, plants and animals and cause health problems in humans. Hence the present investigation reveals that heavy metal concentrations are high in some sites of the study area and water is contaminated and not partially suitable for drinking purposes. The results of the study area reveal that, metal concentration in the groundwater to be continuously evaluated and also need for regular groundwater quality monitoring to assess pollution activity.

Recommendations

1. Mass awareness should be generated with regard to human health.
2. Rain water harvesting methods should be encouraged.
3. Supply of protected water.
4. Awareness and training programmes should be conducted for the NGO's and the local people for the sustainable use and management of groundwater of the region.
5. To protect groundwater resources from continuing deterioration and to supply higher quality water for human consumption, there is a need to assess the quality of water periodically
6. A detailed hydrogeohemical investigation and water management is suggested for sustainable development of the water resources of the area for better human health.
7. With regard to heavy metals problem in groundwaters the best suggestion to avoid health risks is to have wells checked frequently. Moreover, many of the aforementioned prevention methods can be incorporated to help reduce metals leaching from the soil into the groundwater.

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