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Heavy Metal Contamination of Groundwater in Nacharam Industrial Area, Hyderabad, India

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ABSTRACT

Samples of Groundwater, surface water, soil and sediment were collected from the region in and around Peddacheruvu (Irrigation Tank) near Hyderabad City, India. Water samples are analyzed for heavy metals with Inductively Coupled Plasma Mass Spectrometer. Soil and sediment samples were analyzed for heavy metals with X-ray Fluorescence. From the analytical data of heavy metals, it is found that the soil samples are contaminated with heavy metals such as As, Cu, Cr, Pb, Rb, V, Zn and Zr. The high contamination of soils with heavy metals may be due to anthropogenic sources since the country rock of granite does not contain these heavy metals with such high concentration. The contaminated soils have contributed the contamination to both the sediments and groundwater. The sediments have the high concentration of heavy metals such as As, Ba, Cr, Rb, Pb, Zn and Zr, while the groundwater is contaminated with heavy metals such as Al, Mn, Fe, Ni, Zn, Cu and Pb. Interestingly, surface water is less contaminated with heavy metals namely Fe, Mn, Ni and Al when compared to the sediment and groundwater as these heavy metals are deposited on the sediment due to the heavy metal precipitation activity in the water body.

Key words: Heavy Metal contamination, Groundwater, Surface water, Soil and sediment, Nacharam Industrial area, Peddacheruvu, Mass spectrometer, X-Ray Fluorescence

INTRODUCTION

Hyderabad is one of the metropolitan cities in India. Due to the rapid industrialization and urbanization, many industries located in and around the city have released their untreated and semi treated effluents into the environment, more particularly to the water bodies. Even the pollutants such as heavy metals and other chemicals, which are present in the effluents moved through soil, surface water, sediments of the lake bed and percolated into groundwater affecting the soil and groundwater quality.

The present study is aimed at carrying out an estimation of heavy metals in the study area to find ground water quality since it is the source for drinking, domestic and industrial purposes. In view of the above, a case study is taken up near Nacharam Industrial area located in greater Hyderabad metropolitan city. The study area is chosen because this site stands as a testimony for industrial pollution particularly due to the presence of heavy metals in the soil, sediment and groundwater.

This study helped in investigating the heavy metal contamination in soil, surface water, sediment and groundwater,thereby establishing the pathway of the heavy metal movement in the subsurface.

It is well established that high concentrations of heavy metals are dangerous to animals, plants and human lives, cause many kinds of diseases. Even the so-called essential elements like Zn and Fe, if present in high concentrations, are toxic in nature (Aswathnarayana, 1995; Govil, 2001). The heavy metals react with the organic acids like humic acid and form complexes (Davis, 1984). These complexes help the pollutants to migrate faster in the soil (Seather et al., 1997). Eventually, the pollutants percolate down and contaminate the aquifer in the area. Heavy metals accumulate in soil and present a serious long-term hazard. (Bates, 1972; Page, 1974; Prohic et al., 1997). All heavy metals are not harmful to humans, but at high concentration levels they are toxic in nature. Studies have shown that toxic metals in soil influence plant growth (Davis and white, 1981; Alloway, 1995). Combination of low pH and tropical climate play a major role in transporting heavy metals to groundwater through the soil (Govil, 2001). Low pH in stream water will increase the mobility of metals in soil and surface water (Astra and Bjorklung, 1995).

In the present study, an attempt is made to establish the pathway of heavy metals from soil to ground water through surface water and sediments

The Study Area

The study area is a part of Nacharam Industrial area Figure 1. It is located to the north-east of Hyderabad, in the adjacent Ranga Reddy district. It is spread in an area

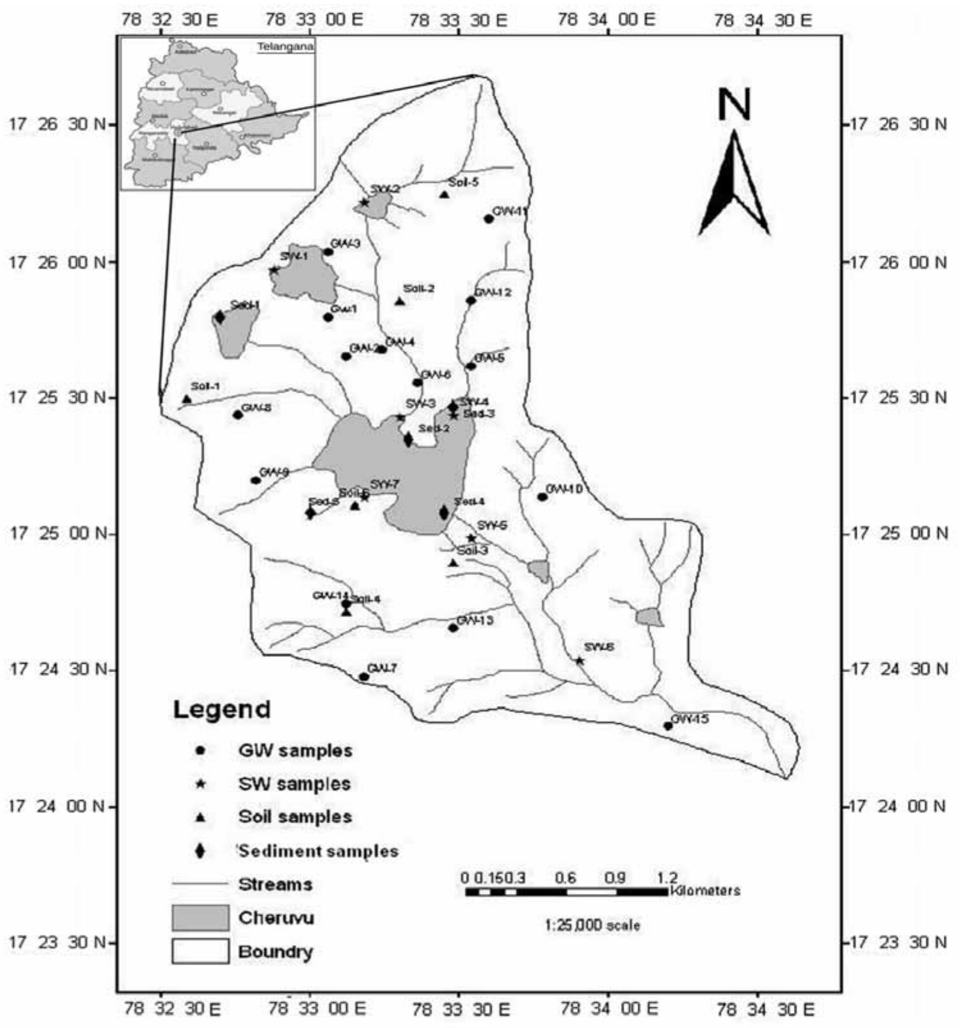

Figure1. Samples location map

of about 280 hectares. It lies between the East longitudes 78º 32′ 30" to 78º 36′ 30″ and North latitudes 17º 23' 30" to 17º 26' 30" and forms a part of Survey of India toposheet No. 56K/11/ NW. Approximately 100 industries including steel manufacturing, chemical manufacturing, food products, rubber and plastics and breweries industrial units are located in the study area.

Collection of Soil, Sediment and Water Samples

Surface water, groundwater, soil and sediment samples were collected in the month of April, 2009 Figure 1. Seven surface water samples were collected from Peddacheruvu and its streams. Fifteen groundwater samples were collected from the bore wells in and around the study area. The water samples were collected in one litre polythene bottles. Prior to collection, the bottles were rinsed 2-3 times with water and completely filled to avoid air bubbling. Surface water samples are filtered with Whitman filter paper No. 42 before analysis, whereas for Groundwater samples, pH, EC and TDS values are measured on the same day after collection of the samples. Six soil samples were collected at 5-15 cm depth from the ground surface. Normally, industrial pollutants contaminate the upper layer of soil (up to 40 cm). Five sediment samples were collected from Peddacheruvu. Soil and sediment samples are collected in self-locking polythene bags and are dried for 3-5 days and disaggregated with a Mortar and Pestle and pellets were prepared. Then soil and sediment pellets were prepared for XRF analysis.

METHODOLOGY

To achieve the objectives, groundwater, surface water, soil and sediment samples in the study area were analyzed for heavy metals. Surface and groundwater samples were analyzed for Al, V, Cr, Mn, Fe, Ni, Co, Cu, Zn, As, Sr, Mo, Cd, Sb, Ba, Pb, and B by Inductive Coupled Plasma –

Table 1. Concentrations of Heavy Metals in the Soil Samples as Analyzed by XRF Spectroscopy

Sample-ID	As ppm	Ba ppm	Co ppm	Cr ppm	Cu ppm	Mn (%)	Ni Ppm	Pb ppm	Rb ppm	Sr ppm	V ppm	Fe_2O_3 (%)	Zn ppm	Zr ppm
Soil-1	85.7	825.2	12.0	38.3	678.2	0.05	36.3	215.2	90.4	172.4	97.3	3.25	305.2	223.8
Soil-2	19.5	813.3	16.5	49.6	45.2	0.06	30.3	80.3	82.9	150.7	118.7	4.29	138	359.7
Soil-3	32.7	500.0	10.2	13.4	21.5	0.05	17.7	98.9	144.6	153.6	87.0	3.2	104.6	493.0
Soil-4	13.5	1218.0	21.8	60.5	30.0	0.03	37.4	57.8	112.5	216.2	142.0	3.25	148.4	1388. 7
Soil-5	13.0	524.7	6.6	88.5	38.3	0.05	18.7	55.5	32.1	209.2	79.7	4.42	160.4	407.6
Soil-6	15.0	1061.0	19.6	22.4	29.6	0.04	21.6	57.7	146.6	210.0	171.8	253.0	147.7	402.0

Table 2 . Concentrations ($\mu g/l$) of Heavy Metals in the Surface Water Samples as Analyzed by ICP-MS.

Sample-ID	Al	V	Cr	Mn	Fe	Ni	Co	Cu	Zn	As	Sr	Mo	Cd	Sb	Ba	Pb	B
SW-1	4.1	3.0	2.0	8.8	200	7.6	0.74	2.1	4.23	1.83	548.2	1.9	0.02	0.09	100	0.07	98.8
SW-2	18.0	2.0	2.0	104	182.0	6.9	0.6	2.8	15.1	1.6	516.8	1.1	0.08	0.12	103.5	0.29	99.0
SW-3	70.0	10.0	24.0	355.0	371.0	22.7	4.9	8.63	134.0	3.06	1085.0	2.8	0.16	0.32	105.9	6.28	293.0
SW-4	8.5	3.0	2.0	23.6	163.0	6.2	0.4	2.7	23.9	1.4	485.1	1.1	0.04	0.12	86.6	8.08	1.5
SW-5	16.0	2.0	2.0	39.5	167.0	6.3	0.6	2.8	19.2	1.5	490.6	1.3	0.06	0.12	91.5	0.46	95.7
SW-6	20	3.0	2.0	12.7	176	8.5	0.6	2.8	14.2	1.6	499	1.5	0.05	0.15	88.9	7.0	100.0

Mass Spectrometry (ICP-MS). Similarly, soil and sediment samples were analyzed by X-Ray Fluorescence (XRF) for heavy metals including As, Ba, Co, Cr, Cu, Mn, Ni, Pb, Rb, Sr, V, Fe_2O_3, Zn and Zr.

Discussion of the results of Soil Sample Analysis

The concentrations of heavy metals in the soil samples are as shown in the Table 1.

The diffusion and convection of water in the industrial effluents through soil involve a series of complex processes that are very important in environmental studies (Govil et al., 1999). From Table 1, it can be observed that the soil samples have the heavy metals such as As (85.7 ppm), Cu (678.2 ppm), Cr (88.5 ppm), Pb (215.2 ppm), Rb (146.6 ppm), V (171.8 ppm), Zn (305.2 ppm) and Zr (1388.7 ppm) in high levels and exceeded the world's average abundance in soil (ICRCL, 1987). This high concentration clearly indicates that source of contamination is not the host rock (granite), but it is due to various anthropogenic sources such as industrial wastes, agricultural wastes, and domestic waste dumped on the land and surrounding Peddacheruvu as observed from the field survey. High values of Ba and Sr up to 1000 ppm and 300 ppm, respectively can be assumed to be derived from the surrounding rocks. But high concentrations of 1218 ppm and 1061 ppm of Ba in soil-4 and soil-6, respectively indicate pollution from surrounding industries. The study reveals that the enhanced top soil values generally indicate a non lithogenic source of contamination (Ull rich et al., 1999). The soil sample-1 has As, Cu, Pb, Zn and Zr in high concentration. Such high contamination could have originated primarily from garbage dumps, wastages from dairy form, painting and printing wastes, as observed in the field. In rainy season, all the heavy metals and chemicals in the wastes are washed out and moved through adjacent streams and infiltrated into the ground, polluting both the surface and groundwater bodies.

To know the spatial distribution of heavy metal contamination in the soil, contour maps of heavy metal concentration have been prepared. The contaminated soils have contributed the contamination significantly to both sediments and groundwater. The contamination is found to be less in the surface water.

Discussion of the results of Surface Water Sample Analysis

The concentrations of heavy metals in the surface water samples are as shown in the Table 2.

From Table 2, it can be observed that the heavy metals such as Be, B, V, Cr, Co, Cu, Zn, As, Mo, Cd, Sb, Ba, and Pb in surface water are within permissible limits. Concentrations of some heavy metals such as Fe, Mn, Ni and Al in surface water are mostly within permissible limit, but in specific places these contents have exceeded BIS permissible limit. The sample SW-3 has high concentration of Fe (371 $\mu g/l$), Mn (355 $\mu g/l$), Ni (22.7 $\mu g/l$) and Al (70 $\mu g/l$) while the nearby sample SW-2 has high concentration of Mn (104 $\mu g/l$). The sample SW-3 is collected from the place where debris of buildings are dumped near Peddacheruvu and drainage stream from the

Table 3. Concentrations of Heavy Metals in the Sediment Samples as Analyzed with XRF Spectroscopy

Sample-ID	As ppm	Ba ppm	Co ppm	Cr ppm	Cu ppm	Mn (%)	Ni ppm	Pb ppm	Rb ppm	Sr ppm	V ppm	Fe_2O_3 (%)	Zn ppm	Zr Ppm
Sed-1	14.7	861.9	17.4	30.0	37.3	0.03	23.4	64.3	100.7	238.1	115.7	2.88	103.3	553.1
Sed-2	23.7	881.8	12.7	38.5	49.5	0.05	30.8	78.6	109.9	191.0	104.2	3.93	180.0	670.0
Sed-3	13.6	1208.0	29.5	24.4	26.4	0.05	14.4	61.0	121.1	206.5	204.7	3.58	134.4	1011
Sed-4	5.4	760.8	5.9	19.8	57.3	0.05	17.1	41.1	478.6	268.1	93.7	3.26	120.3	1727
Sed-5	13.2	934.5	17.8	26.6	21.9	0.05	16.8	60.4	105.2	181.6	140.4	5.19	87.3	801.8

Table 4. Concentrations (μg/l) of Heavy Metals in the Groundwater Samples as Analyzed with ICP-MS

Sample-ID	Al	V	Cr	Mn	Fe	Ni	Co	Cu	Zn	As	Sr	Mo	Cd	Sb	Ba	Pb	B
GW-1	13.0	14	15	45.7	80.7	4.11	0.31	4.9	38.4	2.6	232.4	0.7	0.05	0.02	22.4	1.6	52.2
GW-2	138	10	25	680	386	16.9	1.9	11.5	3587	2.3	1509	4.4	0.4	0.3	340	18.5	253
GW-3	42	10	23	2597	488	20.4	11.5	11.3	249	2.09	1493	4.8	0.2	0.07	82.6	3.27	203
GW-4	9.4	15	3.0	0.08	189	8.76	0.62	5.01	11.4	2.72	514.8	4.9	0.03	0.29	97.24	0.02	195
GW-5	82	10	20	2219	535	18.3	1.8	11.7	720	3.05	1351	3.3	0.32	0.09	122.3	5.42	161
GW-6	45	10	23	857	347	16.2	1.9	7.1	277	2.3	1699	4.2	0.18	0.08	121.3	5.99	231
GW-7	150	12	21	270	457	14.3	1.5	7.7	218	3.4	1609	2.7	0.18	0.12	176.9	10.1	485
GW-8	51	10	22	122	462	21.3	2.06	7.8	272	2.09	1738	2.2	0.1	0.13	113.2	10.9	220
GW-9	49	16	3.0	3.4	70.5	2.2	0.11	5.5	30	2.1	142.1	0.8	0.04	0.09	44.4	1.2	68
GW-10	3.8	2.0	2.0	3.2	100	2.9	0.1	3.1	29.5	0.4	169.7	3.2	0.02	0.04	56	0.04	104
GW-11	17	2.0	2.0	514	280	8.5	2.6	6.1	41.1	1.1	686.9	1.4	0.07	0.03	64.1	0.88	59
GW-12	87	12	23	300	589	19	15	10	339	2.9	1495	3.0	0.3	0.1	274	13	314
GW-13	6.4	11	3.0	3.8	246	8.3	0.5	3.1	20.8	1.2	628.3	0.6	0.04	0.02	121.4	1.1	72
GW-14	1.0	2.0	2.0	145	212	6.6	0.4	1.2	24.6	0.9	450	1.1	0.03	0.03	132.7	0.04	43.3
GW-15	95	11	21	40	370	11.8	0.51	604	1807	2.5	1774	1.0	0.36	0.3	210	21.3	189

residential houses enter the Peddacheruvu. It is interesting to observe that the surface water is not retaining all the heavy metals that are discharged from the soil.

Discussion of the results of Sediment Sample Analysis

Sediment samples collected from the Peddacheruvu have been analysed. The concentrations of heavy metals in the sediment samples are as shown in the Table 3. The heavy metals namely As (23.7 ppm), Ba (1208 ppm), Cr (38.5 ppm), Rb (478.6 ppm), Pb (78.6 ppm), Zn (180 ppm) and Zr (1727 ppm) are observed in high concentration in sediment samples. In soil samples also, these metals are found in high concentrations. But in surface water, no such heavy metals are found in high concentrations. The other studies also revealed that most of the urban and industrial runoff contains a component of trace and heavy metals in the dissolved or particulate form (Defew et al., 2005). Heavy metals from incoming soil runoff and fresh water sources are rapidly removed from the water body and are deposited on the sediment (Gunzman and Garcia, 2002). There is a chance that the heavy metals in surface water are deposited slowly on the sediment due to heavy metal precipitation activity from water.This was indicated in the present study.

Discussion of the results from Groundwater Sample Analysis

The concentrations of heavy metals in the groundwater samples are as shown in the Table 4. In the study area, heavy metals such as Be, V, Cr, Co, Cu, As, Sr, Mo, Cd, Sb, Ba and B are within permissible limits while Al (150 μg/l), Mn (2597 μg/l), Fe (589 μg/l), Ni (21.3 μg/l), Zn (3587 μg/l), Cu (604 μg/l) and Pb (21.3μg/l) have high concentrations in ground water samples.They are more than BIS permissible limits. The sample Nos. GW-2, 7, 8 and GW-15 have all these metals in high concentration.

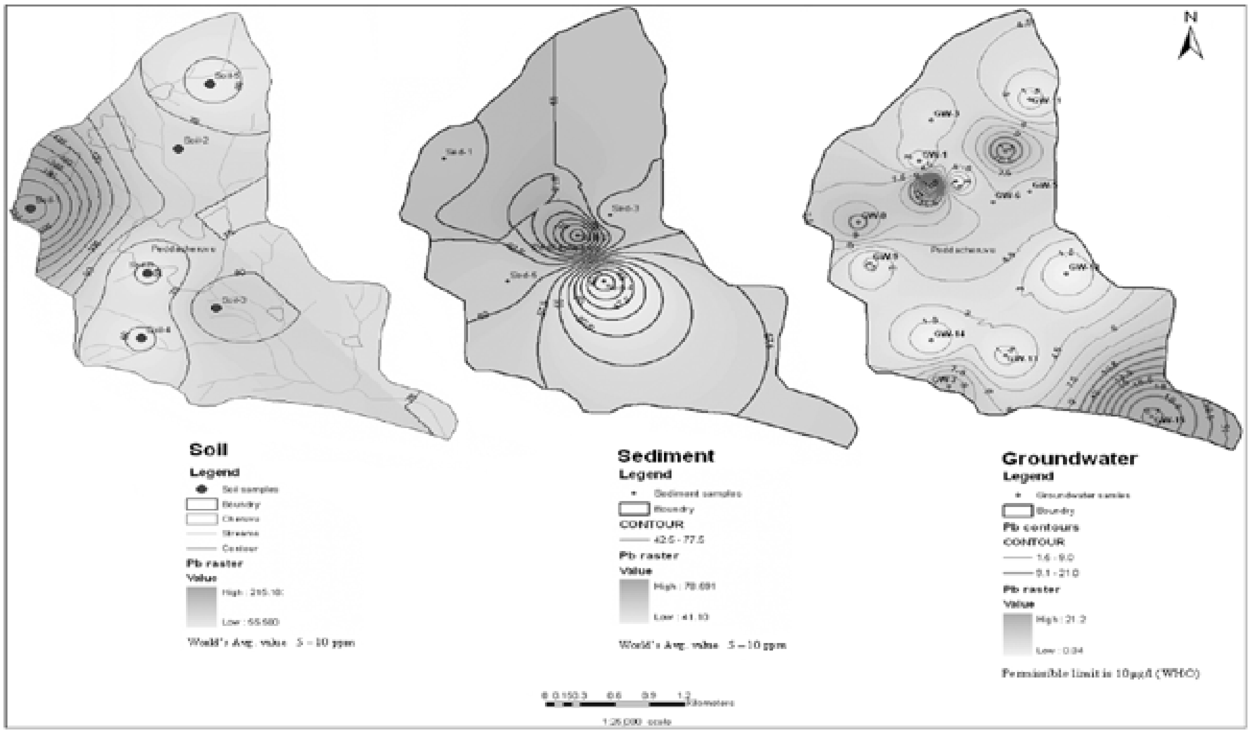

Figure 2. Pb Distribution in soil, sediment and groundwater Samples (µg/l)

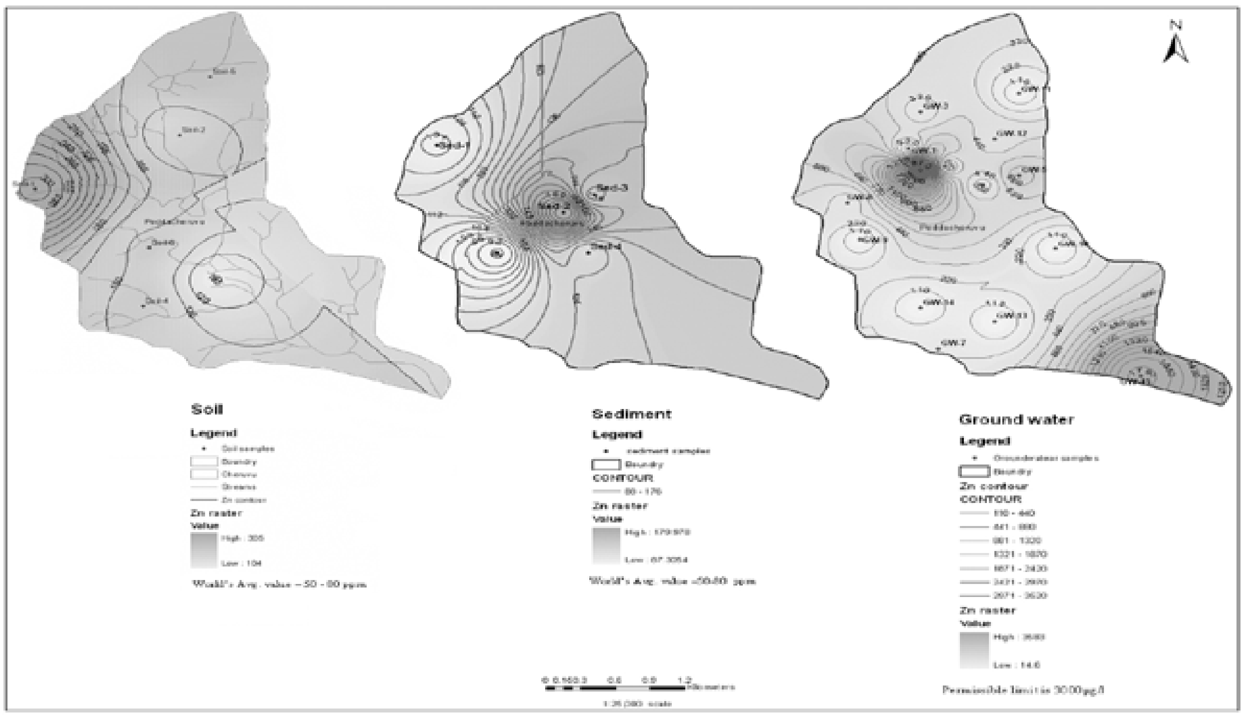

Figure 3. Zn Distribution in soil, sediment and groundwater samples (µg/l).

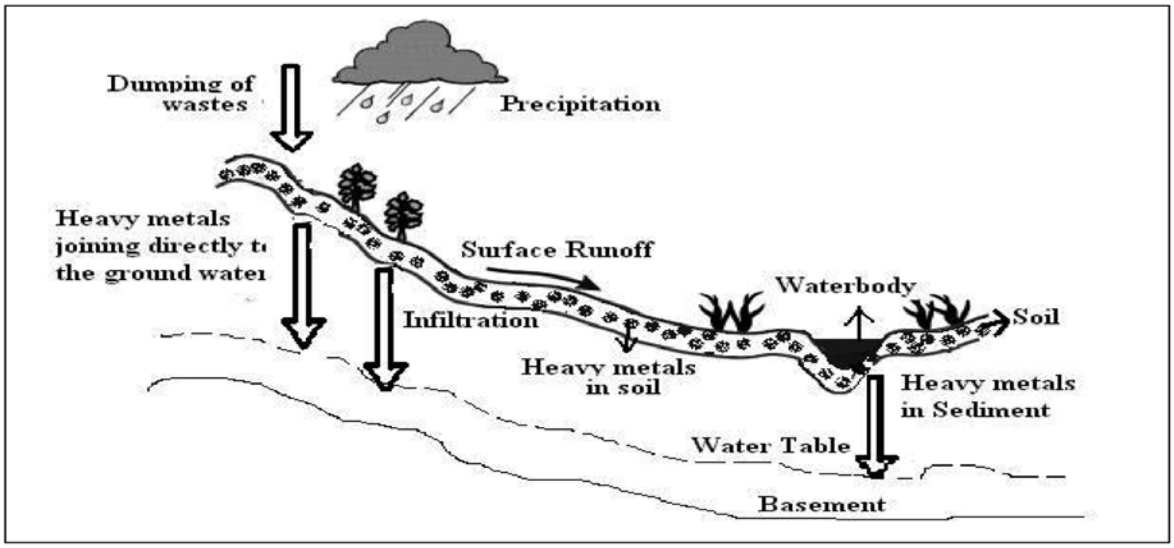

Figure 4. Pathway of Heavy Metals to Groundwater

The heavy metal presence in groundwater occurs naturally in some concentration, based on the type of host rock. However, it raises to high levels or toxic levels due to the release of heavy metals from contaminated soil, sediment and leachate. When the runoff percolates into the ground, the heavy metals, which are present in soil move through water. As these metal pollutants move through water, some elements react with other metals and adhere on soil surface. The remaining reach groundwater. This mobilization of heavy metal depends on the soil pH, ion exchange capacity, oxidation state of heavy metals and physico-chemical characteristics of soil, sediment and heavy metals (Evans, 1989). In the study area, the metals such as Pb and Zn are observed in the soil and in the sediment samples with high concentrations. There is a possibility that these metals reach the groundwater from soil and sediments, as depicted in the contour maps of soil, sediment and groundwater Figure 2 and Figure 3. From these figures, it can be observed that the lead and Zinc, which are primarily concentrated only in a particular spot in the soils, got spread out laterally during their mobilization from soil to sediment and then to groundwater.

Thus, the groundwater is getting polluted with accumulated concentrations of dangerous heavy metals. Such a pollution trend is a cause of huge concern as the polluted groundwater is being used for drinking and other domestic purposes.

The Pathway of the Heavy Metals in the Study Area

There is an accumulation of heavy metals in the soil initially due to the dumping of industrial effluents and domestic waste on the ground. During the monsoon season, the heavy metals are directly reaching the groundwater source through the infiltrated water from the soils. The heavy metals also travel to the nearby surface water bodies through surface runoff generated from these contaminated soils. However, the surface water bodies are not retaining major quantum of the heavy metals, as they (due to heaviness) go down and usually get deposited in the sediments of the lake bed. Consequently, some of these heavy metals from the sediments reach the groundwater, in the form of recharge from the lakes and reservoirs Figure 4.

CONCLUSIONS

The soil in the study area is contaminated with heavy metals such as As (85.7 ppm), Cu (678.2 ppm), Cr (88.5 ppm), Pb (215.2 ppm), Rb (146.6 ppm), V (171.8 ppm), Zn (305.2 ppm) and Zr (1388.7 ppm). These high concentrations are not associated with the host rocks. The high level of heavy metal contamination is basically due to anthropogenic sources and dumping of wastes on the surface.

The surface water is contaminated with Fe (371 μg/l), Mn (355 μg/l), Ni (22.7 μg/l) and Al (70 μg/l). These concentrations are comparatively less despite the fact that the building residuals are dumped near Peddacheruvu and the drainage from residential houses is entering the Peddacheruvu at this place. This is because the heavy metals are precipitated and settled in the sediments. Therefore Sediment samples in the study area are also heavily contaminated with heavy metals such as As (23.7 ppm), Ba (1208 ppm), Cr (38.5 ppm), Rb (478.6 ppm), Pb (78.6 ppm), Zn (180 ppm) and Zr (1727 ppm) just like in the soil samples.

The heavy metals in the groundwater are in the following order: Al (150 μg/l), Mn (2597 μg/l), Fe (589 μg/l), Ni (21.3 μg/l), Zn (3587 μg/l), Cu (604 μg/l) and Pb (21.3 μg/l). The groundwater contamination with heavy metals shows that the contaminants have reached ground water from high level releasing sources such as contaminated soil, sediment and runoff leachate. This dynamic mobilization process has helped in establishing pathways for the heavy metals to reach the ground water.

It appears that the pathway of the heavy metals enabled an accumulation of heavy metals in the soil initially, when the industrial effluents and domestic dumpings are spread on the ground. During the monsoon season, the accumulated heavy metals are mobilizing freely and directly reaching the groundwater body by traveling along the infiltrated water from the soils. The heavy metals are also traveling to the nearby surface water bodies through surface runoff generated from these contaminated soils. But the surface water is not retaining all the heavy metals and most of them are getting precipitated in the sediments of the lakebed thereby joining the groundwater.

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