ORIGINAL RESEARCH PAPER

Environmental Science

ASSESSMENT OF HEAVY METAL POLLUTION IN WATER RESOURCES AND THEIR IMPACTS AT RENIGUNTA INDUSTRIAL COMPLEX, CHITTOOR DISTRICT, ANDHRA PRADESH

KEY WORDS: Groundwater, Water quality parameters, Water Quality Index, Spatial distribution, Renigunta.

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ABSTRACT

Heavy metals in water are extremely essential to living organism but concentration beyond the limit recommended by various national and international organization may cause physiological disorders. Excess of these in water environment occurs, via a wide range of process and pathways, by natural and anthropogenic sources. Accumulation of these metals in living organism can be toxic and carcinogenic due to its non-biodegradable nature. For this purpose water, quality management and assessment in light of heavy metal is of prime importance. The overall water quality status and identification of source of origin of heavy metals are required for water quality management.

INTRODUCTION

The term 'heavy metals' refers to any metallic element that has a relatively high density and greater than 4 g/cm3[1]. Few metals in minute amount are necessary for metabolic activity in human system while others cause acute and chronic diseases [2]. Heavy metals enter into aquatic system by natural and anthropogenic sources. During the last two centuries, heavy metals released by anthropogenic influence have superimposed its contribution by natural source [3]. Water pollution because of these elements is the major environmental as well as socio economic problem. Various water quality management strategies has been implemented to safeguard water from pollution. Heavy metals reviewed in this paper include some significant metals of biological and environmental toxicity, such as iron (Fe) , lead (Pb), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), chromium (Cr), arsenic (As), nickel (Ni) and manganese (Mn). To understand the impact of heavy metal contamination of water, the manuscript will explore its sources, impact and assessment techniques [4].

2. SOURCES OF HEAVY METALS

Heavy metals of excessive concentration in water environment occur via a wide range of process and pathways by natural and anthropogenic sources. The natural source includes wet and dry deposition of atmospheric salts, water-soil and water-rock interaction. Anthropogenic sources comprise rapid urbanization and industrialization.

2.1. Natural Source

Occurrence of heavy metal in water by natural sources depends on the local geology, hydrogeology and geochemical characteristics of the aquifer [5]. The basic source of elements polluting the water body is by weathering of sedimentary rock like limestone, dolomite, shale, sandstone. Interaction of water with igneous rock such as granite, gabbro, nepheline syenite, basalt, andesite, ultramafic also contributes some major elements. The specific minerals or ores that on dissolution increase the level of elements are magnetite, hematite, goethite, siderite (Fe); calcite, cuprite, malachite, azuite (Cu); chromite (Cr); kaolinite, montmorillonite, arsenic trioxide, orpiment, arsenopyrite (As); calamine, smithsonite (Zn); pyrolusite, rhodochriste (Mn) [6]. As is also found concentrated in sulfide-bearing mineral deposits, especially those associated with gold mineralization; and hydrous iron oxides ores [14]. Few minor elements like Cd, Co, Mn occurs in earth crust along with other minerals [15]. Apart from this Ni, Pb and Hg get deposited into aquatic system from dry or wet fall out of atmospheric aerosols formed from wind-blown dust, volcanic emissions, forest fires and vegetation [7].

2.2. Anthropogenic Source

The rapid pace of industrialization and urbanization decreases the carrying capacity of water sharply. The concentration level of Hg in water increases mostly due to agricultural activities, human activities such as tillage and logging, domestic sewage discharge, atmospheric deposition from solid waste incineration, coal and oil combustion, pyrometallurgical processes (Fe, Pb and Zn) and mining activities. Surface runoff from rain or snow brings Hg contaminated soil to adjacent water systems [8]. Industrial processes which are responsible for polluting water with Hg includes chloralkali, batteries, fluorescent lamps, thermometers, and electronic switches production. Chemical industry has been among the largest intentional polluting source of mercury in the world [9]. The anthropogenic source of Ni is from the corroded metal pipes and containers. Lead in aquatic environment comes from compounds like paints and petrol additives and precipitation of aerosols formed from high temperature industrial process such as coal combustion, smelting and cement production . Cd enters into water system through industrial discharge and galvanized pipe breakdown. Cadmium is also present in phosphate fertilizers act as one of the source of polluting agent in water body. Cu normally occurs in drinking water from copper pipes, industrial waste, as well as from additives designed to control algal growth. Fe and Mn in water comes from industrial effluent, acid-mine drainage, sewage and landfill leachate. Anthropogenic source of Cr includes discharge of industrial wastewater from various industries such as metallurgical (steel, ferro- and nonferrous alloys), refractories (chrome and chrome-magnesite) and chemical (pigments, electroplating, tanning and other) [10]. Sources of As in aquatic ecosystem includes nonferrous mining, mineral extraction, combustion of fossil fuels and wastes, poultry and swine feed additives, pesticides. Other sources also include incineration of municipal and industrial wastes, wood preservatives and through the roasting of arsenious gold ores. The load of Zn in water system is closed or ongoing oremining activities. Most of the heavy metals in aquatic ecosystem is contributed to elevated level through acid mine drainage (AMD), one of the most serious environmental hazards from the mining industry. The AMD is generated by the oxidation of sulphide bearing minerals exposed to weathering conditions resulting in low quality effluents characterized by acidic pH and a high level of dissolved metals (e.g., As, Cd, Cu, Zn) and anions (e.g. sulphates and carbonates) [11].

3. IMPACTS OF HEAVY METALS CONTAMINATION

Heavy metals enter into human body through drinking water obtained from a various sources like wells, rivers, lakes, reservoirs, ponds etc. The occurrence of metals in the drinking water beyond the recommended limit prescribed by various national and international organization can cause health hazard. Moreover, Ni and Hg are carcinogenic and cause damage to DNA (Deoxy ribo-nuclicacid).Ni also causes systemic toxicity, allergy, hair loss and anemia. Pb, one of common heavy metal in general beyond desirable limit is metabolic poison and enzyme inhibitor. It can also damage nervous connections and cause blood and brain disorders. Other than this the biochemical effects of lead is its interference with haemosynthesis, which leads to haematological damage. Fe and Mn at low concentration is needed for enzyme activity but at high concentration, it accumulates in muscle, liver

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and affects brain and central nervous system. Cr known as carcinogenic and toxicological agent can cause dermatitis and ulceration of the skin. Long-term exposure can cause kidney, liver damage, circulatory and nerve tissue damage. As at higher concentration can cause lesions on skin, hyperpigmentation, respiratory complications, hormonal change, chronal renal failure. Zn as needed in lower concentration for acting as catalyst in enzyme activity of living system but it accumulates in muscle and liver. The chronic health effects of Zn include cancer, birth defects, organ damage, disorders of the nervous system and damage to the immune system. The Cd, classified as toxic trace element appears to accumulate with age, especially in the kidney and it is considered as an agent to cause cancer and cardiovascular diseases. Industrial contaminated drinking water causes bone and renal disease. With long-term exposure it can replace calcium in bones and damage kidney. Cd may interfere with the metallothionein's (a protein that binds to excess essential metals to render them unavailable) ability to regulate Zn and Cu concentrations in the body which causes elevation in zinc in urine. Cu exposed for long term or high concentration can cause chronic diseases like nervous system disorder, liver and kidney failure. Elevated level of Cu in drinking water can also cause vomiting, abdominal pain, nausea, diarrhoea and anemia [12].

STUDY AREA

The study area covers Renigunta town which is 9 km away from holy city Tirupati. It lies betweem 13°39'0'' North, 79°31'0'' East. Renigunta is a census town in Chittoor district of Andhra Pradesh. The total population of Renigunta was 26,031 (Census India, 2011)[13]. Renigunta's climate is classified as tropical. In winter, there is much less rainfall than in summer. Average annual temperature is 28.6°C. Average precipitation is 939 mm (climatedata.org, 2015)[14]. The location map of the study area is shown in Figure 1.

MATERIALS AND METHODS

Sample collection

Groundwater samples were collected from 12 locations (Figure 2) during post-monsoon period (November 2017). Each of the groundwater samples was analyzed for 16 parameters include pH, total dissolved solids, total hardness, calcium, magnesium, sodium, potassium, sulphate, bicarbonate, chloride, nitrate and fluoride, and heavy metals such as iron, copper, chromium and cadmium using standard procedures recommended by APHA. The results were compared with BIS 10500:2012 standards (Table 1) and WQI was calculated for each and every sample by considering WHO standards (Table 1).

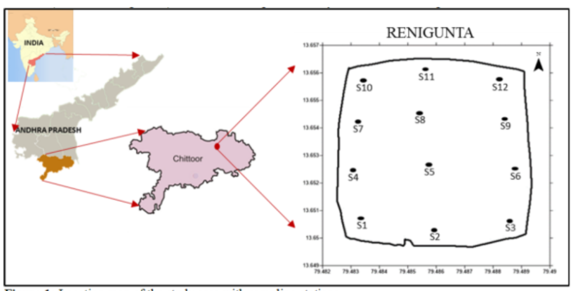

Figure 1: Location map of the study area with sampling stations.

Table 1 Drinking water quality standards according to BIS (10500:2012) and WHO

Parameter	BIS		WHO Standards
	Desirable Limit	Maximum Permissible Limit	
pH	6.5-8.5	No relaxation	7.0-8.5
TDS	500	2000	500
Total Hardness	200	600	100
Calcium	75	200	75
Magnesium	30	100	50
Sodium	-	-	200
Potassium	-	-	12
Sulphates	200	400	200
Bicarbonate	-	-	500
Chlorides	250	1000	200
Nitrates	45	No relaxation	45
Fluorides	1.0	1.5	1.5
Iron	0.3	No relaxation	0.3
Copper	0.05	1.5	0.05
Lead	0.01	No relaxation	0.01
Chromium	0.05	No relaxation	0.05
Cadmium	0.003	No relaxation	0.003

*All units except pH are in mg/

Water Quality Index

In computing WQI, first of all, each of the selected parameters has been assigned a weight (wi) based on their perceived threat to the water quality. The maximum weight was assigned to parameters which have major importance in water quality assessment. Minimum weight was assigned to the parameters which may not be harmful (Papiya Mandal et.al, 2012 and Jasmin et. al 2014)[15] (Table 2). Then, the relative weight (Wi) is calculated using following equation:

Wi=Wi Wini=1

Where, Wi is the relative weight, wi is the weight of each parameter and n is the number of parameters. Calculated relative weight (Wi) values of each parameter are also mentioned in Table 2.

Table 2 Weightages and Relative weights of water parameters

Chemical Parameter	Weight (wi)	Relative Weight (Wi)
pH	4	0.0754
TDS	4	0.0754
TH	2	0.0377
Ca^{2+}	2	0.0377
M g2+	2	0.0377
Na+	2	0.0377
K+	2	0.0377
$SO4^{2-}$	4	0.0754
HCO3 ~	3	0.0566
Cl-	3	0.0566
NO3 ~	5	0.0943
F-	4	0.0754
Fe	4	0.0754
Cu	2	0.0377
Cr	5	0.0943
Cd	5	0.0943

Lastly, a quality rating scale (qi) for each parameter is calculated using following equation:

$$qi = (Ci/ Si) \times 100$$

Where, Ci is concentration of each parameter, and Si is standard concentration of each parameter according WHO guidelines for drinking-water quality (4th ed.).

After that SI (Sub index) is determined for each parameter, which is then used to determine the WQI as per the following equations

$$SIi=Wiqi$$

$$WQI = \Sigma Sii$$

Based on computed WQI values of less than 50, 50-100, 100-200, 200-300 and greater than 300, water quality is classified as excellent water, good water, poor water, very poor water, and water unsuitable for drinking.

RESULTS AND DISCUSSION

Results of physico-chemical analysis of groundwater samples are presented in Table 3.

Table 3 Results of Physico-Chemical analysis of ggroundwater samples

Parameter	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12
pH	7.3	6.9	7.2	6.8	6.7	7.2	7.1	7.1	6.9	7.4	6.9	6.7
TDS	1620	1806	2008	1374	1882	1836	1454	1876	2194	2326	2032	2024
TH	290	326	288	240	292	416	398	460	442	538	480	526
Ca^{2+}	102	76	106	77	66	152	69	55	52	70	50	56
Mg^{2+}	28	38	31	28	46	29	27	36	54	37	55	41
Na+	235	299	316	289	222	286	249	248	273	292	256	266
K+	11	12	23	11	11	9	9	12	19	16	18	16
$SO4^{2-}$	93	138	125	119	296	106	95	268	190	156	144	170
HCO3	530	490	568	430	442	676	344	358	408	426	392	436
Cl-	182	168	338	112	236	138	107	208	360	302	194	210
NO3	18	16	21	24	19	36	29	68	59	74	88	82
F-	0.4	0.4	0.8	1	0.4	1.1	0.8	1	1.2	0.8	0.7	0.7
Fe	0.22	0.38	0.42	0.35	0.47	0.55	0.41	0.49	0.61	0.36	0.58	0.53
Cu	0.31	0.31	0.31	0.32	0.34	0.33	0.35	0.33	0.32	0.33	0.31	0.29
Cr	0.058	0.059	0.058	0.057	0.058	0.056	0.06	0.062	0.059	0.06	0.054	0.052
Cd	0.782	0.736	0.748	0.79	0.798	0.752	0.786	0.802	0.859	0.826	0.762	0.71

*All units except pH are in mg/l

At all the stations, pH is within limits given by BIS. Not even single station have TDS concentration within desirable limit and it ranges from 1374 to 2326 mg/l. TH ranges from 240 to 538, thus at all the sampling stations the TH is more than the desirable limit. Calcium concentrations are within the desirable value of 75 mg/l except at S1, S2, S3, S4 and S6. Magnesium concentration at S1, S4, S6, and S7 are well within the desirable limit, whereas at remaining stations concentration of magnesium was found to be more than desirable and less than permissible limits. Sodium values ranges from 222 to 316 mg/l and Potassium ranges from 9 to 23 mg/l. Sulphate concentration varied from 93 to 296 mg/l and it is more than desirable limit at only two stations i.e., S5 and S8. The Concentration of bicarbonate ranges from 344 to 676 mg/l. At S9 and S10, chloride concentration is more than 250 mg/l, whereas at remaining stations chloride concentration less than 250 mg/l. Out of twelve stations, seven stations have nitrate concentration less than 45 mg/l. The stations having nitrates concentration more than 45 mg/l are S8, S9, S10, S11 and S12. The fluoride concentration more than the desirable limit of 1 mg/l is found at S6 and S9, while remaining are within desirable limit.

Concentration of iron ranges from 0.22 to 0.61 mg/l and it is within desirable limit only at S1. The concentration of copper ranges from 0.31 to 0.35 mg/l. That means at all the stations copper concentration is within desirable limits. At all the stations chromium concentration is more than desirable limit and it ranges from 0.052 to 0.062 mg/l. Cadmium is found to be in excessive levels at all the stations. Cadmium concentration ranges from 0.71 to 0.859 mg/l which is more than the desirable limit of 0.003 mg/l given by BIS.

The computed WQI values ranges from 2388 to 2866. So groundwater in the study area is unsuitable for drinking. The higher values of WQI are due to higher values of cadmium in the groundwater. Spatial distribution of water quality index is shown in Figure 2.

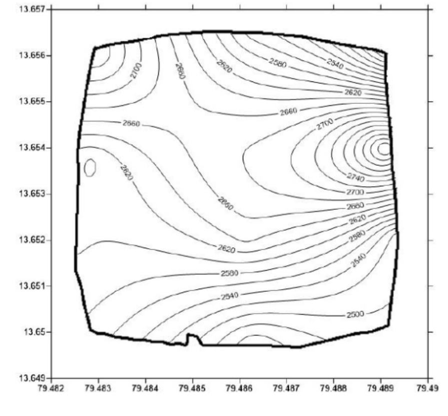

Figure 2: Spatial distribution of water quality index.

CONCLUSION

The source of heavy metal in aquatic environment is natural and anthropogenic. Natural sources include weathering of mineral enriched rocks, precipitation of atmospheric salts generated from natural processes such as volcanic eruptions, forest fire, etc. The major anthropogenic source includes the discharge of wastewater, sludge from industrial activities. Agronomic and household activities also elevate the level of heavy metals in the adjoining water system. Combustion of fossil fuels, incineration of municipal as well as industrial waste, vehicular and industrial emissions generate aerosols, which fall out as dry and wet precipitation also contaminate the aquifers. The concentration of heavy metals in drinking water beyond the recommended limit prescribed by various national and international organization causes acute and choric diseases. These can be nonfatal such as such as muscle and physical weakness to an extent of fatal for example brain, nervous system disorder and even cancer.

For the safeguard of human health and environment throughout investigation of water quality is required. The first step is to access the overall quality of water and then identify the source of pollutants to diminish the level of pollution. Heavy metal pollution index is well-documented method to check the status of water with respect to heavy metals. Factor analysis proved an effective method to identify the source of origin of heavy metal polluting the water body. Application of both approaches subsequently represents the actual status and understanding of water body and further helps in preparing a management plan to reduce the pollution level. It is observed that chromium and cadmium concentrations are more than permissible limits in the study area, especially cadmium levels are very high. Chromium and Cadmium are carcinogenic, so proper treatment is required. As per WQI, the groundwater in the study area is unsuitable for drinking. Necessary measures are to be taken to supply safe drinking water to the people living in study area. The final output has been given in the spatial distribution of water quality index in the study area.

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