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APPLICATION OF HEAVY METAL POLLUTION INDEX FOR GROUND WATER QUALITY ASSESSMENT IN ANGUL DISTRICT OF ORISSA, INDIA

Rizwan Reza
Research Scholar, Dept. of Environmental Science and Engineering, Indian School of Mines, Dhanbad, Jharkhand, India (E-mail: raza_ism@rediffmail.com)
Gurdeep Singh
Professor and Head Dept. of Environmental Science and Engineering, Indian School of Mines, Dhanbad, Jharkhand, India
Gurdeep Singh
Associate Professor Dept. of Environmental Science and Engineering, Indian School of Mines, Dhanbad, Jharkhand, India

Abstract: *Heavy metal pollution index (HPI), a technique of rating water quality, is an effective tool to assess the water quality with respect to heavy metals. Eighteen groundwater samples were collected from open and tube wells during pre-monsoon and post-monsoon seasons. The concentrations of trace metals such as cadmium (Cd), copper (Cu), iron (Fe), lead (Pb) and zinc (Zn) were determined by using atomic absorption spectrophotometer. The values of HPI of the samples were found in the range of 31-87 in pre-monsoon season while 30-77 in post-monsoon season, which found below the critical index limit of 100. The higher concentration of dissolved metals during pre-monsoon season exhibits poor quality of water as compared to post-monsoon season. It may be due to more dissolution of metals during rock-water interaction in relatively stagnant and low flow of ground water in pre-monsoon season.*
Keywords: *Ground water; seasonal variation; heavy metal pollution index (HPI); industrial activities; Orissa.*

1. INTRODUCTION

Water is a most important resource for mankind existence and economical development. Peoples around the world have used groundwater as a source of drinking water, and even today more than half the world's population depends on groundwater for survival (UNESCO, 1992; Rajankar et al., 2009). In India, due to the scarcity of surface water in many regions, ground water is becoming an important source of drinking water supply (Kumar and Bahadur, 2009). The value of groundwater lies not only in its wide spread occurrence and availability but also in its consistent good quality, which makes it an ideal supply of drinking water (UNESCO, 1992). There has been tremendous increase in the demand of potable water due to the rapid increase in the population and industries (Rao and Mamatha, 2004). The overexploitation of ground water resources and discharge of untreated effluents induces degradation of ground water quality. Heavy metals enter in ground water from variety of sources; it can either be natural or anthropogenic (Reza and Sing, 2010; Akoto et al., 2008; Adaikpoh et al., 2005). Usually in unaffected environments the concentration of most of the metals is very low and is mostly determined by the mineralogy and the weathering of that area (Panda et al., 2006; Karbassi et al., 2008). Main anthropogenic sources of heavy metal contamination are mining, disposal of untreated and partially treated effluents as well as metals chelates from different industries and indiscriminate use of heavy metal-containing fertilizer and pesticides in agricultural fields (Nouri et al., 2008; Rao and Mamatha, 2004; Karbassi and Amirnezhad, 2004; Amman et al., 2002; Khan et al., 2005; Sahu, 1998; Hatje et al., 1998).

The behaviour of heavy metals in the environment depends on their inherent chemical properties. Trace metal contaminations are important due to their potential toxicity for the environment and human beings (Vinodhini and Narayanan, 2008; Wong et al., 2003; Nayak et al., 2001). Some of the metals such as Zn, Fe, Ni, Mn and Cu are the essentials micronutrients required for metabolic activity in organisms to sustaining aquatic biodiversity, but there is a narrow gap between their essentiality and toxicity. Toxic heavy metals can accumulate in the bodies of aquatic organisms, including fish, making them unfit for human consumption (Nouri et al., 2008; Ammann et al., 2002).

Heavy metal pollution control (HPI) is defined as a rating reflecting the composite influence of different dissolved heavy metals. HPI is calculated from the point of view of the suitability of groundwater for human consumption with respect to metal contamination. Ground water is one of the major sources of drinking water in the study area so it was important to assess the ground water quality with respect to heavy metal contamination.

2. MATERIALS AND METHODS

Study Area

The study area is lies between latitudes 20° 37′ N to 21° 10′ N and longitudes 84° 53′ E to 85° 28′ E and situated at an average height of 139 meters above mean sea level (MSL). The area is characterized by Precambrian granites, gneisses and schists of Eastern Ghats with local intrusive and volcanic lithologies; lime stone, sand stone and shales of the Gondwanas (Panda et al., 2006; Sundaray et al., 2006). At present, it accommodates several large and medium scale industries such as Nalco Smelter and its Captive Power Plant (CPP-960MW), Talcher Super Thermal Power Station, NTPC (TSTPS-3000MW), Talcher Thermal Power Station (TTP-460MW), Iron and Steel industries and various coal mines. The drainage pattern is controlled by the River Brahmani along with its tributaries. The area comes under sub tropic monsoon climate with an average annual rainfall of 1370 mm. The temperature varies from 11.9°C to 44.4°C (Sundaray et al., 2006). These mining and other industrial activities can affect the various components of environment including ground water resource in surrounding area

The ground water samples were collected from eighteen different locations including open and tube wells to evaluate the heavy metal contamination during various seasons (pre-monsoon and post-monsoon) within study area. The sampling locations were selected on the basis of different land use pattern, including industrial and residential areas, to quantify metal concentration. The Samples were taken in acid washed plastic container to avoid unpredictable changes in characteristic as per standard procedures (APHA, 2005). Samples were collected for pre-monsoon in May 2007 and post-monsoon in October 2007. Care was taken to collect subsequent samples from same location in both seasons. The collected samples were filtered (Whatman no. 42) and preserved with 6N of HNO3 for further analysis (APHA, 2005). Concentrations of heavy metals in water samples were determined with an Atomic Absorption Spectrophotometer (GCB-Avanta) with a specific lamp of particular metal. Average values of three replicates were taken for each determination. Appropriate drift blank was taken before the analysis of samples. The working wave length for the heavy metals are 248.3 nm for Fe, 213.9 nm for Zn, 324.7 nm for Cu, 228.8 nm for Cd, 217 nm for Pb. Details of sampling location is illustrated in Table 1.

Table 1
Details of Water Sampling Location Along with their Longitude and Latitude

Code	*Sampling Locations*	*Latitude*	*Longitude*
GW1	Gotamara village, tube well	20° 51′ 21″	85° 12′ 46″
GW2	Dasnala Village, open wel	20° 53′ 33″	85° 14′ 33″
GW3	Jgannath village tube well	20056′50″	850 10′40″
GW4	Kandasar Village, open well	20° 50′ 33″	85° 07′ 58″
GW5	Girang Village, open well	20° 50′ 52″	85° 10′ 08″
GW6	Gopal Pd village,Tube well	20° 50′ 30″	85° 06′50″
GW7	Sharma Chak, open well	20° 54′ 44″	85° 11′15″
GW8	Donara village, Open well	20° 56′ 36″	85° 06′12″
GW9	Hingula tube well water	20° 56′ 32″	85° 11′57″
GW10	Takua Village, open well	21° 06′ 04″	85° 03′10″
GW11	BarhGundari Village, open well	21° 04′ 47″	85° 00′ 02″

Contd...

GW12	Kamarel village open well	210 02′ 10″	850 02′50″
GW13	Akgharia Village, open well	210 02′ 38″	850 09′39″
GW14	Banarpal junction, tube well	20° 50′ 28″	85° 12′55″
GW15	Nuashahi village, open well	200 48′ 10″	850 09′00″
GW16	Tulsipal village,open well	200 49′ 00″	850 07′40″
GW17	Longibeda village, tube well	200 47′ 50″	850 04′ 20″
GW18	Gadrak khai village, open well	200 48′ 20″	850 09′30″

Heavy Metal Pollution Index

Heavy metal pollution index (HPI) is a technique of rating that provides the composite influence of individual heavy metal on the overall quality of water. The rating is a value between zero and one, reflecting the relative importance individual quality considerations and defined as inversely proposal to the recommended standard (*Si*) for each parameter. Water quality and its suitability for drinking purpose can be examined by determining its quality index (Prasad and Kumari, 2008; Mohan et al., 1996; Reza and Singh, 2010).

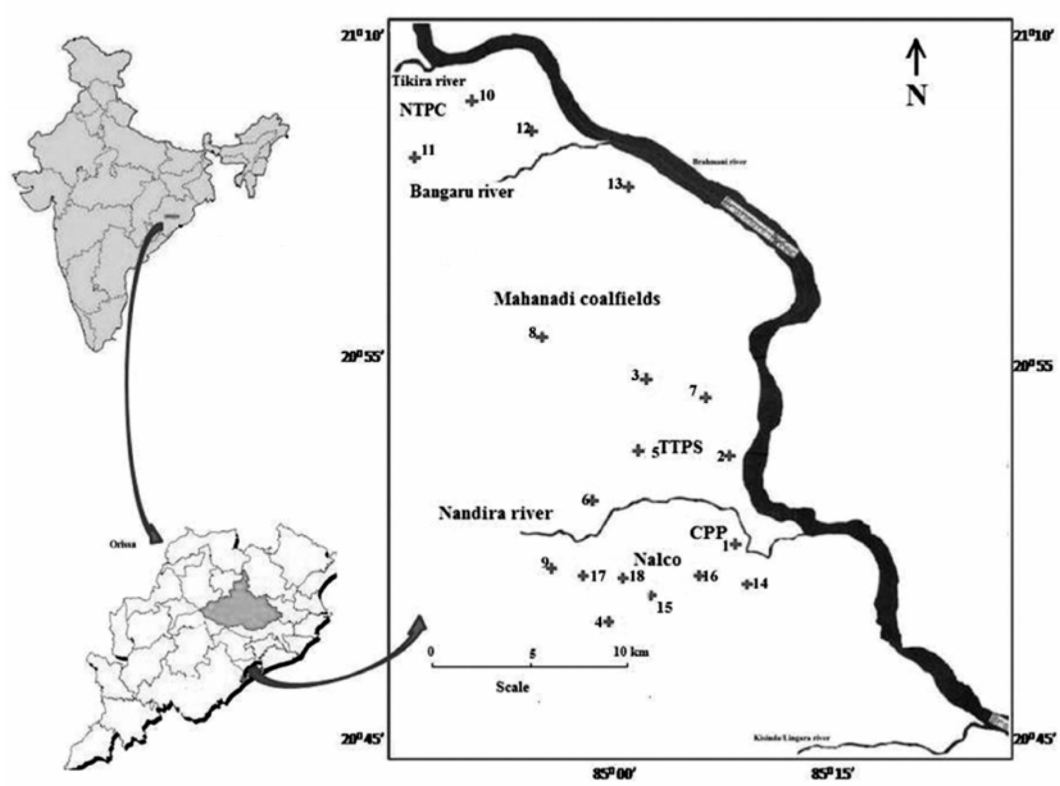

Figure 1: Map of Study Area Along with Sampling Locations

The calculation involves the following steps

First, the calculation of weightage of i^{th} parameter

Second, the calculation of the quality rating for each of the heavy metal

Third, the summation of these sub-indices in the overall index

The weightage of i^{th} parameter

$$w_i = k/S_i \quad (1)$$

where W_i is the unit weightage and S_i the recommended standard for i^{th} parameter, while k is the constant of proportionality.

Individual quality rating is given by the expression

$$Q_i = 100\ V_i/Si \quad (2)$$

where Q_i is the sub index of i^{th} parameter, V_i is the monitored value of the i^{th} parameter in µg/l and S_i the standard or permissible limit for the i^{th} parameter.

The Heavy Metal Index (HPI) is then calculated as follows

$$\text{HPI} = \sum_{i=1}^{n}(Q_iW_i) \Big/ \sum_{i=1}^{n}W_i \quad (3)$$

where Q_i is the sub index of i^{th} parameter. W_i is the unit weightage for i^{th} parameter, n is the number of parameters considered. The critical pollution index value is 100.

3. RESULTS AND DISCUSSION

Statistical analysis showed that the metal concentrations were significantly different between sampling stations. However, the heavy metal concentrations were found within the permissible limit (IS: 10500). The Table 2 showed that the mean concentrations of Zn, Cu, Pb Cd and Fe, which are widely distributed in the geological environment due to the weathering of minerals containing rocks and soils (Fatoki et al., 2002). The metal concentrations were higher in the pre-monsoon than the concentration occurred in winter season except the lead (Pb). The higher concentration of metals in pre-monsoon season may be assigned to the soil-water interaction during almost stagnant or low flow of ground water facilitates the dissolution of metals ions (Venugopal et al., 2009).

Table 2
HPI Calculations for the Ground Water Based on the Indian Drinking Water Standard (IS: 10500, 1993)

Heavy metals	*Mean concentration (Vi)*		*Highest permitted value for water (Si)*	*Unit weightage (Wi)*
	Pre-monsoon	*Post-monsoon*		
Pb (μg/l)	14.8	16.7	50	0.1393
Cd (μg/l)	4.9	3.4	10	0.6968
Zn (μg/l)	12.8	10.8	15000	0.0014
Cu (μg/l)	3.5	3.0	1500	0.1393
Fe (μg/l)	32.8	21.8	1000	0.0232

In order to calculate the HPI of the water, the mean concentration value of the selected metals (Pb, Cd, Zn, Cu, Fe) have been taken into account. In Table 2 detailed calculation of HPI with unit weightage (W_i) and standard permissible value (S_i) are presented for study. The values of Heavy Metal Pollution Index (HPI) is to be found in the range of 31-87 (mean = 52.2) in pre-monsoon and 30-77(mean = 41.5) in post-monsoon season. The highest values of HPI were found in the sample o Jagannath village tube well (GW3 = 82), Kandasar Village, open well (GW4 = 85), Akgharia Village, open well (GW13 = 86) and Nuashahi village, open well (GW15 = 87) respectively while during post-monsoon the values of same are reduced up to 50, 67, 78 and 69 respectively. The higher values of HPI may be attributed to rock-water interaction during low flow or stagnant of ground water during pre-monsoon season. Lower values in post-monsoon season indicate the dilution affect due to seepage or percolation of rain water. The HPI values of the samples within study area are found below the critical pollution index (100), above which the overall pollution level should be considered unacceptable (Prasad and Kumari, 2008; Mohan et al., 1996 Reza and Singh, 2010). This indicates the water is not critically polluted with respect to heavy metals. However, it is not very far from the critically pollution index value (100). Figure 2 represent the HPI values of various locations.

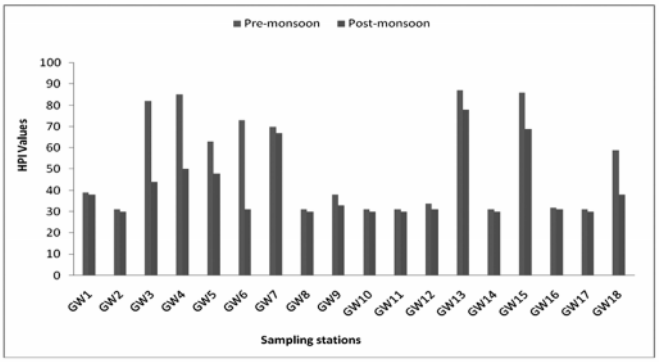

Figure 2: HPI Values at Various Sampling Points in Pre and Post Monsoon Seasons

4. CONCLUSIONS

On the basis of Heavy Metal Pollution Index (HPI), dissolved metals concentrations in ground water were slightly high in the pre-monsoon than the concentration occurred during post-monsoon season. The maximum values of HPI were 87 and 77 in pre-monsoon and post-monsoon season respectively. Higher value indicates the dissolution of metals from existing rocks to ground water during pre-monsoon was predominant as compare with seepage or percolation of metals contaminants during post-monsoon season. However the ground water samples are not critically contaminated with respect to heavy metals but the values are not very far from the critical limit (100).

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